I.29/12: 20/10

CRM

CULTURAL RESOURCE MANAGEMENT
Information for Parks, Federal Agencies, Indian Tribes, States, Local Governments, and the Private Sector

VOLUME 20 NO. 10 1997

A Unity of Theory and Practice
Bridging to the Past

The University of Pennsylvania and the NPS

U.S. DEPARTMENT OF THE INTERIOR
National Park Service
Cultural Resources

PUBLISHED BY THE NATIONAL PARK SERVICE

To promote and maintain high standards for preserving and managing cultural resources

DIRECTOR
Robert Stanton

ASSOCIATE DIRECTOR
CULTURAL RESOURCE STEWARDSHIP AND PARTNERSHIPS
Katherine H. Stevenson

EDITOR
Ronald M. Greenberg

PRODUCTION MANAGER
Karlota M. Koester

GUEST EDITORS
Jake Barrow
Frank Matero

ADVISORS
David Andrews
Editor, NPS
Joan Bacharach
Museum Registrar, NPS
Randall J. Biallas
Historical Architect, NPS
Susan Buggey
Director, Historical Services Branch
Parks Canada
John A. Burns
Architect, NPS
Harry A. Butowsky
Historian, NPS
Pratt Cassity
Executive Director,
National Alliance of Preservation Commissions
Muriel Crespi
Cultural Anthropologist, NPS
Mark R. Edwards
Director, Historic Preservation Division,
State Historic Preservation Officer, Georgia
Roger E. Kelly
Archeologist, NPS
Antoinette J. Lee
Historian, NPS
John Poppeliers
International Liaison Officer
for Cultural Resources, NPS

CONTRIBUTING EDITORS
Kay D. Weeks
Technical Writer-Editor, NPS

CONSULTANTS
Wm. H. Freeman
Design, Imaging, Production–Freeman Publishing Services
Janice C. McCoy
Editing–Editorial Notes

An electronic version of this issue of *CRM* can be accessed through the *CRM* homepage at <http://www.cr.nps.gov/crm>.

***CRM* CELEBRATING 20 YEARS OF PUBLICATION**

VOLUME 20 NO. 10 1997
ISSN 1068-4999

Contents

A Unity of Theory and Practice

Acknowledgments 3

Celebrating a Five-Year Anniversary—A Model Partnership in the Intermountain Region 4
John Cook

Strategic Planning for Partnership . . .5
Ernest W. Ortega

A Unity of Theory and Practice—Cooperative Research and Training Between the University of Pennsylvania and the NPS 6
Frank Matero

Bridging Fragments to the Past 9
Jake Barrow

Preserving Adobe Ruins 12
Harry C. Myers

A Preservation Action Plan for Fort Union 13
Anne Oliver

The University of Pennsylvania Comes to Fort Davis, Texas 16
Jerry R. Yarbrough

Saving Authentic Surfaces—Plaster and Paint Stabilization at Fort Davis . . .17
Bob Hartzler

A Tale of Two Conservation Projects at Mission San Jose, San Antonio 19
Rosalind Z. Rock

Stability and Integrity—The Convento Stone Column at Mission San Jose 21
Anne Oliver

18th-Century Plasters Preserved—Conservation in the Convento of Mission San Jose 24
Angelyn Bass
Jake Barrow

Inscription Preservation—A Challenge Met at El Morro 27
John Lujan

Rock Art Documentation and Assessment 28
Antoinette Padgett
Kaisa Barthuli

Weathering of the El Morro Inscriptions 30
Stephen Aaron Cross

Epoxies, Grouts, and Inscriptions 33
Dawn Melbourne

Non-destructive Testing at El Morro 35
Marie Ennis

Pilot Conservation at El Morro 36
Anne Oliver

Cliff Dwelling Walls—The Earthen Plaster Project at Mesa Verde 38
Kathleen Fiero

Managing Change—Conservation of Surface Finishes at Mesa Verde's Cliff Dwellings 39
Frank Matero

Materials in the Laboratory—Earthen Plasters, Mortars, and Paints from Mug House 43
Linnaea A. Dix

Ruins Preservation—Pre-Colombian and Historic Ruins Preservation in the Arid Southwest 46
Jim Trott

Acrylic-modified Earthen Mortar . . .50
Bob Hartzler

Cover photos: Field school in progress at Fort Union (top), photo by Angelyn Bass; Teddy Garcia and Wilfred Valencia capping adobe walls at Fort Union (bottom), photo by Bob Hartzler.

Statements of fact and views are the responsibility of the authors and do not necessarily reflect an opinion or endorsement on the part of the editors, the *CRM* advisors and consultants, or the National Park Service. Send articles and correspondence to the Editor, *CRM* (2251), U.S. Department of the Interior, National Park Service, Cultural Resources, 1849 C Street, NW, Washington, DC 20240; 202-343-3395, Fax 202-343-5260; email: <ron_greenberg@nps.gov>.

Acknowledgments

Katie McDowell and Christopher Frey at Fort Union Field School. Photo by Bob Hartzler.

This issue of *CRM* presents examples of scientific and technical approaches to preservation. Articles have been edited to render the information as generally applicable as possible without diluting the content. The research and field work presented result from the contributions of many University of Pennsylvania faculty, staff, and students; and National Park Service staff. The projects described herein were developed, managed, and directed by Jake Barrow, Supervisory Exhibit Specialist and Project Manager for the Conservation Program, Intermountain Region, National Park Service; and Frank Matero, Chairman of the Graduate Program in Historic Preservation and Director of the Architectural Conservation Laboratory at the University. Exceptions include the contributions by Antionette Padgett and Kaisa Barthuili directed by Michael Taylor (formerly NPS) and the Mesa Verde efforts which were managed by Kathleen Fiero.

The editors would like to recognize the contributions of Barry Sulam, Program Leader, Conservation Program, Intermountain Cultural Resources Center for continued support of the cooperative agreement and project development; and past and present superintendents of the parks where projects were accomplished including Harry Myers, John Lujan, Jerry Yarbrough, Larry Wiese, Steve Whitesell, Don Spencer, Michele Pelletier, Reed Detring, and Bob Amdor. In addition there are many park and regional staff deserving of thanks including personnel in resource management, maintenance, administrative, and contracting programs. Conservation staffers Patricia Trujillo and Christina Romero provided much back-up support. Special thanks go to Susan Chandoa, Executive Director of Los Compadres de San Antonio Missions for grant assistance for the two represented projects in San Antonio, Texas; and editing assistance from writer/editors Jane Harvey (NPS) and Rosemary Zibart.

Thanks are extended to the many university individuals assisting the projects including Jean Wolf and Suzanne Hyndmann who administered programs at the University; and Andrew McGhee, Rollin Lakis, Xueqin Wang, and Alex Radin, of the Laboratory for the Research on the Structure of Matter (UPenn).

Students not identified in articles and acknowledgments who participated in the various projects over the five-year period include: Eliza Edwards, Peter Ellison, Amy Freitag, Ron Koenig, Sara Korjeff, Sara Pennell, ElizaBeth A. Bede, Florence Antonacos, Suki Diamond, Evin Erder, Rob Fitzgerald, Molly Lambert, Catherine Sellers, Chris Spencer, Stacey Spies, Anu Venkataraman, Almyr Alba, James Banta, Alaa El-Habashi, Andrea Goldwyn, Alison Hawver, Mary Hohl, Dorothy Krotzer, Jackie McCarthy, Michele Salerno, Elizabeth Sippel, Catherine E. Turton, Evan Kopelson, Jay L. Platt, Sara Myer, Veronica Aplenc, Elisa Del Bono, Kristen Fetzer, Karen Fix, Christopher Frey, Mark Goodman, Katherine McDowell, Stephanie Phillips, Kecia Fong, Rynta Fourie, Amy Cole Ives, Jocelyn Kimmel, Lorraine McVey, Jessica Sloop, Christeen Taniguchi, Catherine Turton, Sarah Meyer, Renee Jones, and Caroline Finch.

Mary Kallenberg provided many hours of volunteer time assisting in several field schools. Zuni preservation trainees Alvin Romancito and Averil Ramirez participated in one field school. In addition to the formal two-plus-week training activities, special presentations and one-day workshops were held to provide management and interested outside parties with program descriptions and explanations.

The National Park Service has been undergoing reorganization in line with the national agenda set forth in the federal government re-engineering effort. The editors have simplified the references to the specific groups within the Park Service by referring generally to the participation as "NPS." In cases of specific projects, this annotation refers to the Conservation Program in the Intermountain Cultural Resources Center of the Intermountain Region of the NPS. Prior to the recent realignment this program was called the Division of Conservation in the Southwest Cultural Resources Center in the Southwest Region of the NPS. As of October 1, 1997, the Center will cease to exist as a separate entity. Those functions will be incorporated into the Southwest Support Office and be fully integrated with all cultural resources management activity for the entire Intermountain Region of the National Park Service. Generally, the Architectural Conservation Laboratory of the Graduate Program in Historic Preservation in the Graduate School of Fine Arts at the University of Pennsylvania is referred to simply as the University of Pennsylvania, UPenn, or the University.

Jake Barrow and Frank Matero

John Cook

Celebrating A Five-Year Anniversary

A Model Partnership in the Intermountain Region

Within the boundaries of the Park Service's Intermountain Region, long esteemed for its great natural areas, are some of the most distinctive, and imperiled, cultural resources in America.

The Region's cultural resources stretch across a broad spectrum beginning with Pre-Columbian sites abounding in the southern reaches, along with a rich variety of Spanish colonial units, each saturated with historic fabric that pre-dates European settlement in the east. As one moves north, there's a host of frontier sites, including the location where the final spike was driven to complete the transcontinental railroad, a frontier cattle ranch, and battlefields important to the Indian Wars.

There are areas that commemorate the Mexican War, the Civil War, and even fairly recent architecture and construction practiced by the Civilian Conservation Corps during the 1930s. In fact, based on legislation, more than half of the Region's parks would be considered as having more historical than natural significance. Since these are more often smaller parks, we have to be extremely sensitive to their needs and vigilant in designing preservation strategies.

University of Pennsylvania student and Fort Union masonry worker repairing adobe walls. Photo by Bob Hartzler.

How do we protect our cultural wealth in the face of downsizing and declining budgets? Now more than ever, we are looking to outside entities for assistance. Our focus is directed toward caring for some of the basic deficiencies we see in our resources without asking for handouts because the fact is we are **not** the only ones with a vested interest in these resources. Yes, we are the caretakers, but the American people and American institutions of all sorts are the owners and beneficiaries. All are enriched by the preservation work we do.

Fortunately, we didn't wait to seek partners until the downsizing began. In March 1992, I signed a cooperative agreement with the University of Pennsylvania. As a result, our labors have already begun to bear fruit. Ever since putting my name on the dotted line, I've followed this project with great interest. And I like what I'm seeing. It's gratifying to watch park staffers get down in the historic dust and debris with university graduate students and come up with original, workable solutions.

Scientists are learning how to deal with day-to-day maintenance and cope with nitty-gritty preservation problems while veteran staffers discover that, at times, theory can be effectively applied to practical issues. New energy and new ideas blend with experience-based know-how to create a powerful synergy which is solving both general and some specific preservation problems at the parks. As you read this issue of *CRM*, you'll learn how a partnership can make this happen.

In the cultural resource area, we are seeking partners whose expertise and resources can join in a common effort to apply the best conservation approaches and methods to achieve our mandated goal of passing on resources **unimpaired.** One of my personal goals, for example, and one that is high on the NPS agenda, is dealing effectively with tribal issues. When I visited El Morro, I was happy to learn more of the consultation with Zuni representatives which occurred because it's a good example of reaching out to and respecting a broader constituency.

This issue of *CRM* is a testament to shared commitment, shared values, and common ground.

John Cook is Director of the Intermountain Region.

Ernest W. Ortega

Strategic Planning for Partnership

Cultural Resource Management in the Intermountain Region is emerging from the restructuring of the NPS with new mandates for comprehensive services. CRM programs in the Santa Fe and Denver Offices; and the Western Archeological and Conservation Center, are charged with the task of providing assistance and services in the disciplines of history, architecture, curation, conservation, archeology, and submerged cultural resources. In the world of shrinking budgets and staff, our increased responsibilities are made even more challenging! Simply put, we have to find new ways of doing things. Partnering is one way to acquire external professional expertise. In particular, collaborations with universities, managed by NPS professionals, have proven beneficial. The continuing cooperative agreement with the University of Pennsylvania, I feel, serves our enlarged clientele—the parks and partners of the Intermountain Region and their resources.

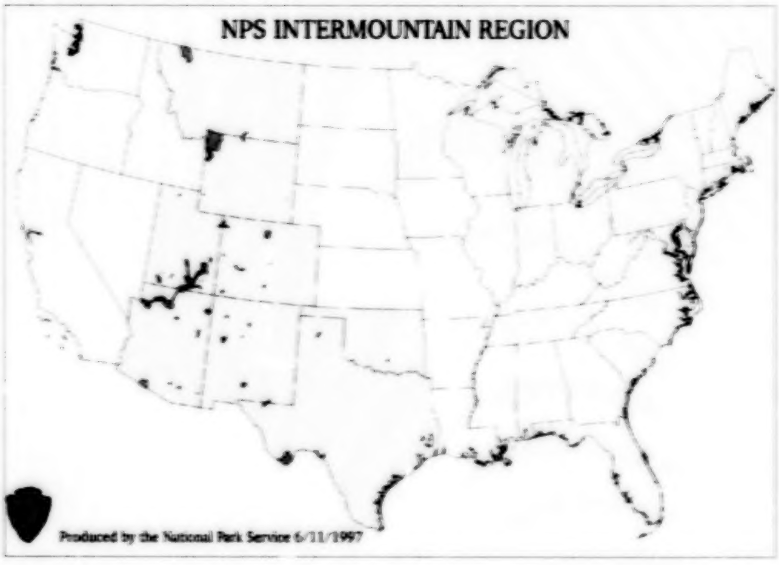
Formal partnerships are essential to developing fully-integrated cultural resources programs throughout our Region. In an April 22, 1996, memorandum, President Clinton directed agencies to work on a legislative proposal "that would make permanently available to the National Park Service the authority to enter into cooperative agreements on behalf of parks." Thus, the utility of public-private partnerships is recognized at the highest level of government. It is appropriate for central Support Offices to maintain these multiple relationships and to avoid overlapping and duplicating services. The examples provided in this issue of *CRM* indicate the value of multi-park initiatives and methodologies being exported from one park to another. The examples further demonstrate how a central office can contribute to on-site preservation projects by making available the benefits of long-term research to park management.

Although our CRM staffs are reduced in size, they are more capable than ever of providing focused preservation services. During the past year, we worked diligently to ensure that the strengths of the programs were re-defined and unified to enhance responsiveness. We intend to consider questions about how best to provide long-term risk management and preventive conservation of the resources under NPS stewardship. Although stop-gap and immediate measures are sometimes needed, we must renew our commitment to long-term solutions. Agreements like the one with UPenn have helped us do just that at San Antonio Missions, Mesa Verde, Fort Union, El Morro, Fort Davis, and most recently, Casa Grande. Partnering, building a team of individuals and institutions, creates stakeholders with mutual interests.

This *CRM* highlights the University partnership and offers us the chance to reflect on and honor five years of professional teamwork, training, and accomplishment in project work and fundamental research. Some of the valuable ideas have been exported beyond NPS to the larger preservation community; let's continue to follow this path.

Ernest W. Ortega is currently the Director of the Intermountain Cultural Resource Center (ICRC) in Santa Fe, NM, and the Western Archeological and Conservation Center in Tucson, AZ. On October 1, 1997, the ICRC will be fully incorporated into the Southwest Support Office.

Map courtesy NPS.



Frank Matero

A Unity of Theory and Practice

Cooperative Research and Training Between the University of Pennsylvania and the NPS

The establishment of the National Park Service in 1916 and its mandate to preserve and manage the country's most significant natural and cultural resources in public trust constitute one of the most important acts of the early preservation movement in the United States. Since that time historic preservation has developed into a professional field which many now consider to be among the most significant and influential of socio-cultural issues of the late-20th century. In 1981, the Graduate Program in Historic Preservation at the University of Pennsylvania was established in response to the rising need to provide a truly integrated curriculum of advanced study for architects, landscape architects, planners, conservators, historians, archeologists, curators, managers, and other preservation practitioners interested in professional careers in building and site conservation and cultural resource management. The program provides students with a foundation in history, theory, technology, and praxis with additional courses selected to structure an area of emphasis within the field of preservation. These areas of specialization are Building and Material Conservation and Cultural Heritage Management for the two-year Master of Science degree and one-year Certificate, the latter for experienced professionals and students enrolled in the school's other professional programs. These emphases encompass a broad range of career options focused on historic monuments and sites, house museums and collections, cultural landscapes, archeological sites, and urban and regional areas. An Advanced Certificate in Architectural Conservation provides an additional opportunity for those who have completed the Master of Science degree with an emphasis in technology. A second internship of one additional semester of supervised applied research is required.

One unique component of the program's commitment to advanced training and technical research in the conservation of the built environment is the Architectural Conservation Laboratory. This technical facility, the only university laboratory of its type in the United States designed solely for teaching and research in the field, provides an intellectual environment within the Graduate School of Fine Arts focused on the development of scientific and philosophically sound solutions to the conservation of our world heritage of historic buildings, monuments, and archeological sites. Through coordinated comprehensive programs of education and research, the Laboratory encourages collaboration between academic and professional resources, addressing major technical issues and field training related to the technical conservation of immovable cultural property. This has

(Below left) Plaster conservation at San Jose Convento. Room #HS203-C north wall, documentation of fragments 19B. Photo by Angelyn Bass.

(Right) The Architectural Conservation Laboratory at the Graduate School of Fine Arts, University of Pennsylvania. Photo by Frank Matero.

1930s field classroom activities in national parks. Courtesy NPS.

been effectively achieved through cooperative agreements established with private and public agencies such as the NPS, the National Center for Conservation, Restoration, and Museology in Havana, Cuba, and Istanbul Technical University.

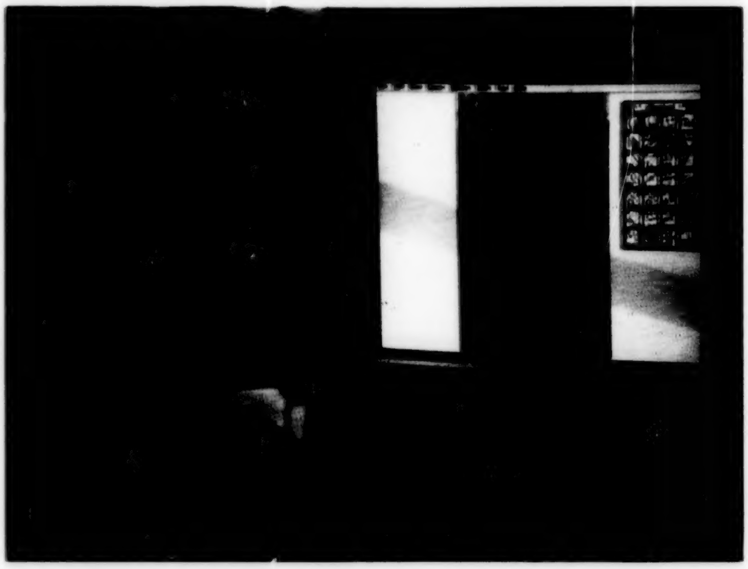
Recognizing the direct and inestimable importance of academic research and training to the preservation and management of our cultural and historical heritage, the University and the former Southwest Region of the NPS entered into a collaborative partnership in 1992, to explore the mutual needs for applied research and training in conservation and cultural resource management. For the past five years, despite shrinking fiscal resources, both institutions have tackled the issues of technical research and professional training in conservation with a global perspective focused on the exigencies of continuing and accelerating deterioration of park resources. As a result of the cooperative agreement, 104 graduate and 18 post-graduate students have received unique experiences across 21 projects.

Field school, Fort Union. Photo UPenn.

As a component of cultural resource management, conservation has as its fundamental objective the protection of cultural property from loss and depletion. Like all disciplines, conservation is a discrete branch of learning based on an agreed-upon body of knowledge and academic training and has emerged as a scientific methodology concerned primarily with the material well-being of cultural property by observing and analyzing the evolution, deterioration, and care of buildings; the conducting of investigations to determine the cause, effect, and solution of building problems; and the directing of remedial interventions focused on maintaining the integrity and quality of the existing historic fabric.

Long recognized for their recreational value, national parks and monuments also provide the public with educational and inspirational opportunities with the country's cultural and natural resources. Early proponents of the National Park Service wisely argued that contact with real things and the ability to have an authentic experience awakens a desire for explanation, for an increase in knowledge making education a continuous process for the greater public. This suggested the development of an active program of applied research and training through the use of the national parks as field laboratories. The germ of the educational idea came into being shortly after its founding with the first director, Stephen T. Mather, through use of the national parks and monuments by universities and colleges as outdoor classrooms or field schools to supplement academic study in the natural sciences. In 1918, recognizing the growing importance of national parks as field laboratories for educational institutions, a National Park Educational Committee was organized, later becoming the National Parks Association. By 1930 the Branch of Research and Education was established in Washington, DC, to coordinate the various educational phases of park work in natural and cultural resources. As stated by the NPS at the time, "Universities may afford better classroom work, better library facilities, and better lectures, but it is believed that nowhere can people find better objective materials for study or receive better training in interpreting phenomena...."

Administering and managing cultural resources have become ever more complex due to the amount of information needed about resources to understand, protect, and preserve them. Critical baseline information and overall internal programming of routine monitoring and evaluation of conditions and interventions are desperately needed. As early as the late 1950s, the Southwest Region recognized this by embarking on a coordinated program of experimentation and monitoring of



Recording conditions surveys on computer. Photo by Frank Matero.

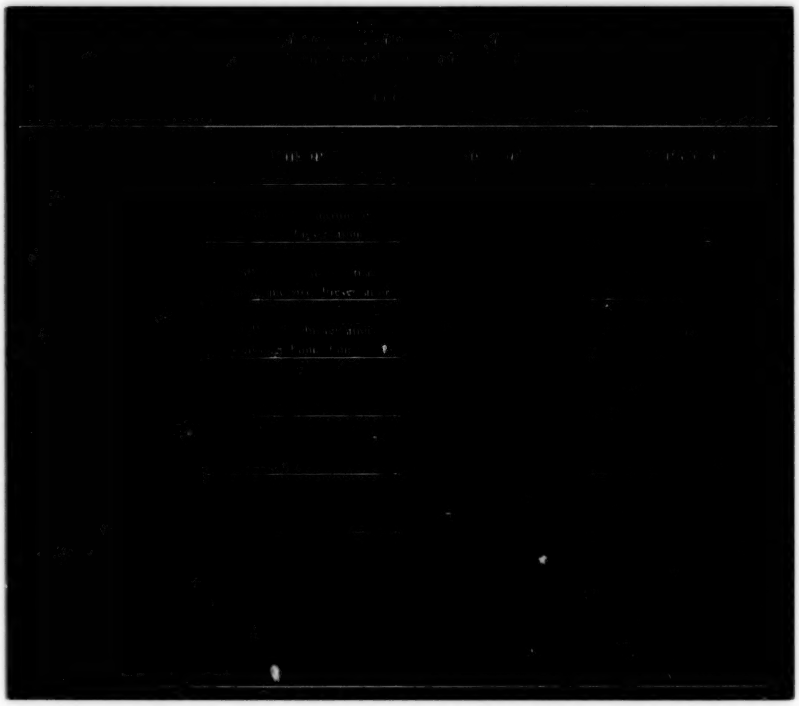
treatment approaches focused on the stabilization of stone and earthen ruins. In the 1970s this expanded to include cooperative research on site testing programs to develop and evaluate current and proposed future treatment considerations. This effort, remarkable for its time, has been nearly forgotten with changes in personnel and management structure, but the partial continuation of the fruits of the research point the way to a methodological approach to long-term resource management rather than what specific products or techniques to use in the short-term.

Now, as then, it is clear that proper interpretation and protection of park resources is dependent upon the possession of accurate scientific knowledge through the development of institutional partnerships. This is especially true for cultural sites, as relevant technical research is heavily underfunded and therefore unavailable for application, and professional conservation involvement has been slower to develop and be applied than for the natural or physical sciences. By identifying and developing park-specific problems as larger topical or regional issues such as the preservation of earthen architecture in arid environments or the monitoring and assessment of ruins deterioration and past preservation treatments, positive and practical approaches can be generated which develop coordinated, long-range solutions while providing better site management and technical assistance to the parks.

Because of the unique multi-disciplinary nature required for the conservation of cultural property, one primary form of information transfer is through supervised work experience. Internship provides immediate and constructive feedback at a critical point in a student's or practitioner's career. The pragmatic mix of improvisation and rigorous attention to detail necessitated by the contingencies of field research make a lasting impression on students who have known only classroom situations. As a result, field experience through graduate and post-graduate internship programs conducted through NPS collaboration has allowed a critical component of the professional training of conservators to be realized while providing much-needed service to park sites.

The basic tenets of conservation are not the sole responsibility of any one professional group. They apply instead to all involved in the preservation of cultural property and represent general standards of approach and methodology. The application of technology must be founded on a profound and exact knowledge of the history of the resource and its context, on the materiality of its physical fabric, on its collective cultural meanings and values over time, and on its role and effect on current society. Ideally the process must be brought back into a resource management strategy so that the conservation project becomes integrated with interpretation and maintenance.

Frank Matero is Associate Professor of Architecture and Chairman of the Graduate Program in Historic Preservation at the University of Pennsylvania. He is guest co-editor of this issue of CRM.



Jake Barrow

Bridging Fragments to the Past

Casa Grande National Monument Field School in progress, January 1997. Photo by the author.

A few days into the new year, I arrived after hours at the headquarters of Casa Grande Ruins National Monument to participate in the final days of the NPS/UPenn field school which had been running since the end of December. In the middle of the group seated at the large conference table (converted for the evening into a dining table) an extra place was set. I received a hearty holiday greeting and a warm plate. It was a lively and engaging evening celebrating two difficult weeks of uncharacteristically cold wet weather for Coolige, Arizona. This was our first winter field school and the group was completing a condition survey of the exterior walls of the multi-story earthen Hohokam monument. While field school tasks have become almost routine after five years, this evening reminded me that historic preservation is not only about materials, techniques, or chemicals, it is a humanistic endeavor of reflecting on and building bridges to our shared past.

During the last five years, our work with the Architectural Conservation Laboratory at the University of Pennsylvania attests to the effectiveness of collaboration. Our successes result from the open exploration of ideas, effective delegation of responsibility, and a humble attitude. Also, we recognize that we do not want to work in an isolated environment and our efforts are enhanced greatly by working together. Our goals are to enlarge the sphere of conservation through state-of-the-art research, to demonstrate field-relevant treatment and to present our work to the public.

The University approaches problems more holistically than the NPS. Its orientation is theoretical: seeing how the problems fit into the whole context of conservation. The NPS budget process, on the other hand, necessitates yearly planning, three years at best. National parks have a host of architectural fabric problems requiring immediate attention: walls falling down, rotting wood, roof deterioration, peeling paint, drainage problems, eroding mortars, etc. To our credit, we usually respond effectively, identifying the worst case situations and making repairs, but our efforts are limited by short-term goals defined by budget cycles. Through collaboration with UPenn, we have been able to meld practical applications with theoretical understanding, focusing on long-term objectives that otherwise would go wanting.

The collaboration began in 1991, when problems were identified at Fort Union National Monument in New Mexico and Fort Davis National Historic Site in Texas. Park managers alerted cultural resource staff about the loss of lime plasters from historic adobe walls. These fragmentary remains record the craftwork of the times and contribute to an important story. The style of interior walls, decorative surfaces, and territorial architecture all evoke 19th-century frontier army life and represent the spirit of westward expansion that seized the country's imagination. As with all fragile architectural fabrics, however, once lost, they can not be recovered. And a general survey of state and federal parks and sites in the West reveals how rare these tactile bits of history are!

Replicating original 19th-century surfaces, however, as with any other authentic material culture, is both unethical and unrealistic. So, in 1992, after a preliminary field pilot season, a multi-year and multi-park conservation effort was launched. From the outset we were not searching for a "quick fix"; rather, we wanted to be part of a continuum, realizing we are neither the first nor the last to do this work.

Fort Union. Our joint effort began by addressing the problem of how to re-establish adhesion of the relatively strong plaster surfaces onto the weaker adobe substrate (earthen bricks). In the course of the collaboration, we discovered

Fort Union summer field school. Photo by Angelyn Bass.

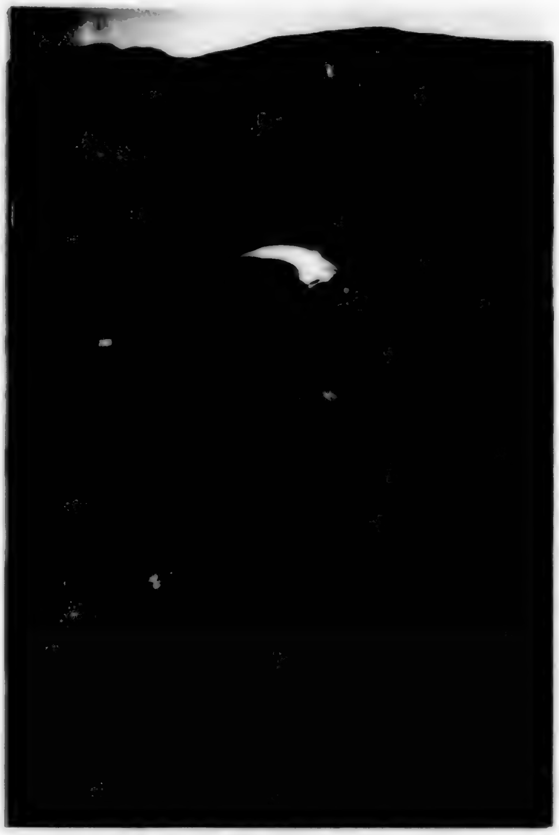
new methods and materials; extensively documented work; and provided graduate students with the opportunity to gain hands-on experience. After several years, our focus expanded to site planning and management. The field school was transformed into a forum on the long-term preservation of adobe ruins. The most recent product has been a preservation action plan which the park can use for 10 to 20 years. The plan addresses the difficult task of managing preservation of an earthen ruin; it doesn't rely only on chemical interventions to strengthen adobe, but targets limited resources to areas requiring different levels of intervention.

Fort Davis. The preservation issues at Fort Union were also relevant to Fort Davis; however, in this setting, a range of treatment philosophies from complete restoration to virtually untouched ruined fabric *in situ* made for a stimulating educational and interpretive environment. It also provided an opportunity to present conservation work as a counterpoint to restoration.

Mission San Jose. Known as "Queen of the Missions," San Jose in San Antonio Missions National Historical Park is considered among the finest Spanish Colonial Baroque architecture in North America. The decorative stonework has been of concern to the NPS for some time. The Cultural Resources Center and the Park recognized the fragility of a column in the ruins of the convento during the late 1980s. A management decision was made to conserve the deteriorating and compromised column instead of replacing it. As a result of earlier inappropriate treatments, some questioned the value of treating the stone at all. This hands-off attitude may be valid in protected sites and interiors but exposed ruins or exterior fabric at risk require protection to mitigate deterioration. The devotion of San Antonians for their missions was proudly indicated when a grant was provided for the preservation project from the park's friends group, Los Compadres de San Antonio Missions. On the heels of this effort, a comprehensive ruins stabilization project was launched. An important spin-off of these collaborations has been a research effort initiated by the local Roman Catholic Diocese with the University focused on some of the ornamental limestone features of San Jose Church.

El Morro. First viewed from the Highway 53 approach, Inscription Rock at El Morro National Monument appears indestructible. Close-up inspection, however, reveals disappearing and fragile inscriptions. Lacking information from previous conservation efforts, the Park and the Cultural Resources Center embarked on a documentation and condition assessment project which led to a series of laboratory studies and field tests including a sequence of non-destructive testing of treatments. A long-term program for inscription preservation was initiated. A new partner was the Zuni tribe, descendants of those who inhabited the region prior to European colonization. The many petroglyphs at El Morro attest to their cultural affiliation, and consultations with tribal representatives led to the development of culturally and technically appropriate treatments based on the NPS goal of managing and slowing deterioration, not stopping natural processes. Our work focused on treating non-native inscriptions. Zuni representatives were comfortable with this approach and our consultations lent credence to the philosophy of tribal inclusion. The pilot work established the viability of a very limited use of applied treatments, selected and localized to specific inscriptions. It continues.

Mesa Verde. Lime plaster preservation at the frontier forts evolved into work on earthen plasters and decorative finishes in pre-Columbian sites. At Mesa Verde National Park, resource managers held preliminary discussions leading to reconnaissance missions at cliff dwelling sites. The park selected Mug House as a project focus. A Getty Institute Grant matched limited available funds and a pilot was launched focusing closely on one set of structures and even more closely on a particular kiva. Other partners included English Heritage which set up a program of environmental monitoring modeled on systems applied at archeological sites in Great Britain. The results represent a holistic approach utilizing computer documentation systems detailing layered data recording of surface phenomena. This pilot work has recently



Stacking new adobes for 1996 test walls at Fort Union. Photo by Bob Hartzler.

been applied to Casa Grande Ruins National Monument where park management had noted the problem of recent surface material losses. Thus, systems, methods, and even specific solutions are exported to other areas.

Long-awaited research findings occurred when the study on uses of an acrylic emulsion earthen amendment, Rhoplex® EC-330, at Mesa Verde, Chaco Culture National Historical Park, and Aztec Ruins National Monument was completed. This thesis by a UPenn grad student serves as a model for the larger inquiry of examining past and current earthen amendments in use throughout pre-Columbian sites in the Southwest. Soil cements and other admixtures continue to be used where field experience warrants.

By our fifth year we have accomplished a tremendous amount. We have collaborated on 20 projects using 11 subagreements and 9 modifications. Our agenda continues to expand. The NPS has a leadership role to play which includes induction of students, co-ops, and trainees into park programs. Our cooperative agreement with the University enables students to join us in preserving vital parts of our American heritage. The University offers its students the opportunity to apply classroom knowledge in the field. The field provides research problems explored through thesis and laboratory work.

The collaboration supports the goals expressed in the Vanishing Treasures Initiative, which is currently providing impetus for NPS ruins preservation in the Southwest. Vanishing Treasures emphasizes long-term programmatic approaches over immediate remedies. It encourages a thorough understanding of the effects of previous and current treatments. As a result, improved record keeping and site monitoring will become accepted practice. The University helps set high standards in these practices.

Cooperative agreements are being scrutinized by NPS administrators to ascertain if each remains aligned with its original purpose and design. It is important to note that the agreements should not circumvent open competition in procurement of services. The cooperative agreement only functions when true collaboration is at work, and each partner is rewarded by the joint effort. The process of accomplishing and managing preservation fabric work remains the internal responsibility of the National Park Service.

The articles presented in this issue of *CRM* provide details of this dynamic, highly productive five-year partnership. The authors all worked with help from parks and Cultural Center staff. The testimonials from administrators show the bond developed between staff, researchers, and preservation technicians. Above and beyond our project results, the greatest achievement has been the development of preservation professionals with an increased knowledge about and commitment to preservation of some of our nation's most precious cultural resources.

Jake Barrow is a Project Manager in the Conservation Program of the Intermountain Cultural Resources Center. He is guest co-editor of this issue of CRM.

Adobe ruins, Fort Davis HB26. Photo by the author.

Harry C. Myers

Preserving Adobe Ruins

It was at the "Adobe '90" conference in Las Cruces, New Mexico, that I met Frank Matero of the University of Pennsylvania. At that conference Jake Barrow and Barbara Zook of the Conservation Program of the Southwest Cultural Resources Center hosted an impromptu meeting about Fort Union National Monument in New Mexico and Fort Davis National Historic Site in Texas. Fort Union National Monument encompasses over 70 acres of adobe ruins, the largest adobe ruins in the United States, and the subject of how best to preserve this military post (active from 1851–1891) was discussed.

Those preliminary discussions led to a pilot field evaluation program in the summer of 1991 where a small but enthusiastic group, led by Frank Matero, assembled to try to find solutions to the problem of original lime plasters falling off the adobe walls. The park could not address this need. The work of keeping the adobe walls preserved occupied all of our preservation crew's time.

Jake Barrow worked with us and UPenn in forging the cooperative agreement. UPenn graduate student Angelyn Bass took on a thesis topic to figure out the best grouting materials for the job. After the field trial and a year's worth of lab work and research, the University team convened the first field school in the summer of 1992.

The project has been a success for Fort Union. Plasters in the Mechanics' Corral have been preserved *in situ*, and the summer field school program has continued through 1997. During all this work our maintenance staff, and particularly supervisor Albert Dominguez, have participated.

The plaster preservation work has led to other valuable assistance to Fort Union. In 1994, Angelyn Bass and Anne Oliver, another UPenn graduate, surveyed all the plaster fragments and performed emergency stabilization on some of the most threatened pieces. In 1995, Anne Oliver and UPenn graduates Bob Hartzler, Linnaea Dix, and James Banta convened at Fort Union to prepare a preservation plan which includes an architectural survey, a wall monitoring system, a test wall program for testing various preservation treatments, and a way for maintenance to prioritize work based on the worst case areas. The test wall program was implemented in 1996, and based on the preliminary results, a capping and shelter coat program were planned for 1997. Bob Hartzler now works as an architectural conservator for the park and field-managed our fiscal year 1997 adobe capping program and plaster conservation field school.

The Fort Union work has been the subject of a scholarly article and has served as one of the initial starting points of cooperation with UPenn. It has re-invigorated our preservation crew. They feel like their work is worth the effort, after having someone from so far away come and pay such close attention to it. Collateral benefits like this one shouldn't be minimized. The program has introduced Fort Union to a scientific method of preservation and as a result, I've seen my staff start working in a new way.

Without the assistance of the University of Pennsylvania and the NPS Cultural Resource Center, Fort Union would still be searching for basic answers to that age-old question of how to preserve something that is deteriorating faster than work can be accomplished on it. UPenn has not given us all of the answers we will need but they have provided us with a framework. We have the plan and some methods; now we're starting to do it.

Harry Myers is Superintendent of Fort Union National Monument.

(Left)
Fort Union 1996 test walls being laid out by UPenn students and park staff. Photo by Bob Hartzler.

(Right)
Fort Union National Monument plaster conservation. Photo by Jake Barrow.

Anne Oliver

A Preservation Action Plan for Fort Union

At Fort Union National Monument, an observation made in 1873 holds equally true today: "The buildings are of adobes and, bare from all plastering, suffer more or less by each rain...."* The Monument's administration has not accepted material loss and has chosen to seek conservation measures to retard deterioration of the ruins; and to help the administration and maintenance staff more effectively manage the preservation of the adobe ruins, a Preservation Plan was developed in 1995. These efforts are part of an ongoing program of maintenance and stabilization managed by the Monument and by National Park Service support functions. The development project is distinguished from the "Draft Preservation Plan" (developed for the Monument in 1988) by its emphasis on active research and the implementation of the results; on interaction between all groups involved; and on the working nature of the document, which will be revised and appended as preservation strategies are refined in the future. The focus of the project was adobe, which was the least understood of the architectural elements remaining in the ruins of Fort Union; adequate preservation measures for the brick, stone, and wooden elements of the ruins were set forth in the "Draft Preservation Plan." The development of the plan took place in the fall of 1995. While the methodology of the project may be applied to other sites or contexts, it should be understood that the results of the project are specific to the site and environment of Fort Union.

Developing the Plan

To gather the knowledge necessary to develop a preservation plan, the project was divided into four parts:

- the review of historic and contemporary documents to outline a history of stabilization and maintenance at the site;
- the physico-chemical characterization of historic adobe and of contemporary repair materials;
- the design and installation of a simple model monitoring system to measure the rate of erosion of adobe; and
- the design and implementation of a general survey of the ruins to understand how the adobe walls weather.

Stabilization and Maintenance

At Fort Union, loss of adobe is inevitable given the (appropriate) mandate of the park to rehabilitate rather than reconstruct. The loss is a result of two factors: gradual attrition, due to erosion by wind, rain, hail, and snow; and catastrophic events, due to wall collapse caused by heavy rains, wind, or lightning strike. Since the inception of Fort Union National Monument in 1956, the maintenance staff has worked to reduce the rate of loss. Maintenance activities can be divided into four major phases:

- 1956-1958: excavation and structural stabilization
- 1959-1962: capping with soil-cement adobes, spraying with silicone water repellent
- 1963-1980: applying soil-cement shelter coats, spraying with silicone water repellent
- 1981-1995: applying unamended soil shelter coats

However, the review of past stabilization and maintenance efforts reveals that the ruins are now at a critical stage. Intermittent estimates of the amount of historic fabric remaining indicate a high rate of material loss despite continuous preservation efforts. The soil-cement wall caps damaged the adobe walls by causing coving, but their protective benefits were long-lasting. A high percentage of caps survive, but these are now cracking and falling.

The use of soil-cement shelter coats was abandoned in favor of less intrusive, more materially compatible shelter coats of unamended soil. Presently, the maintenance staff plans to treat each wall on about a five-year cycle, but the unamended soil shelter coats are ephemeral and must be reapplied as often as twice a year to the same walls. Hampered by the limitations of manpower and materials, the staff was inevitably falling behind.

Historic Adobes and Contemporary Materials

The historic adobes and contemporary unamended repair materials were analyzed at the Architectural Conservation Laboratory of the University of Pennsylvania to gain a better understanding of their physical and chemical properties. The granulometries of the original adobes and of the repair materials fell within the recommended range for adobe; the original adobes and the newest repair materials were the most similar. During the implementation phase of this project, these analyses were used to guide the selection of compatible and effective soils and amendments as alternatives to the materials currently used for maintenance.

An Adobe Monitoring System

A model monitoring system was designed and installed to measure the rate of loss from different locations on adobe walls. Measurements will be

Facility Manager Albert Dominguez and architectural conservator Bob Hartzler evaluate 1996 test walls. Photo by Jake Barrow.

taken over a period of years, and more walls monitored if the system proves adequate. An analysis of the results will increase the body of knowledge on the rate of adobe weathering at critical locations in a wall. By understanding where an adobe wall weathers and at what rate, ruins can be managed more effectively.

The challenges of making accurate measurements of an adobe ruin with simple tools on the northern New Mexico plain are many. They include the materials themselves: weathered, distorted, and leaning earthen walls; and reasonably straight but imperfectly aligned (or partially missing) stone masonry foundation walls. The climate—occasional high winds, thunderstorms, and blowing soil—also contributes to the difficulties of measuring accurately.

Initially, a prototype monitoring system was tested that was completely external to the adobe wall, requiring no installation of monitoring pins or other devices in the wall. It involved a scaffold and plumb lines for finding and measuring points on the wall according to a predetermined grid. This system was abandoned because it was found that the measurements were not reproducible from one day to the next.

For these reasons a system of fixed monitoring pins placed within the walls was selected because it was independent of external alignment and measuring equipment. This system was not without flaws. Invariably some adobe was lost during the installation of the pins, and the pins cannot be removed without risk of damage. But once installed they were not easily noticed against the highly textured adobes. Iron nails were selected for use as monitoring pins; they will weather slowly (and in adobe benignly) in the New Mexico climate, becoming increasingly earth-colored, yet providing measuring points for years to come.

Several factors were considered in selecting areas for monitoring; these included the orientation, exposure, and configuration of the wall as well as the presence of architectural features, such as openings both with and without lintels. Monitoring pins were placed on a grid across the faces, ends, and tops of the walls. More pins were placed in areas known to weather more rapidly, in particular just above the foundation where basal erosion occurs, and below caps where coving occurs. The maintenance staff is measuring erosion from the heads of the pins on a quarterly basis and this data will be analyzed as a part of the implementation phase of the project.

General Survey of Adobe Ruins

The adobe structures of Fort Union encapsulate more than 100 years of cumulative weathering. A major goal of the Development Project was to identify any weathering patterns or trends in order to understand and quantify where, how, and why the adobe structures weather. To what degree was the survival of a wall a function of original construction details, of orientation and exposure, of subsequent configuration or stabilization and maintenance interventions? And what role did coving or basal erosion or even subsequent interventions play in the deterioration of a wall? By answering these questions, cause and effect relationships could be identified, their relative impact on the adobe walls predicted, and preservation interventions prioritized. Also, parts of a wall particularly vulnerable to deterioration could be identified, as could parts of a wall critical to its survival. This knowledge would allow for the development of more effective preservation interventions, in both materials and cost, and for the prioritized application of treatments, where the most vulnerable or critical areas would be given foremost attention. For these reasons a general survey of the adobe ruins of Fort Union was designed and implemented.

The survey was designed with certain preconceptions about where, how, and why adobe walls deteriorate, which were derived from past observations and experiences with adobe structures. For example, orientation and exposure to weather have always been assumed to affect the rate of deterioration, and a harder repair cap, while protecting the wall, has always been assumed to lead to the erosion of the adobe immediately beneath it, leading to coving. The survey was designed to quantify the impact of these suspected factors, but also to record a broader range of information so that unanticipated causes and effects would be revealed.

The adobe buildings at Fort Union have deteriorated into an agglomeration of discrete wall fragments. After the destruction of unifying roofs, floors, and wall intersections in a building, each wall fragment acts independently of the others and may weather differently. Thus the survey was conducted on a fragment-by-fragment level; a two-page survey was completed for each fragment greater than 3-1/2' high; a total of 207 wall fragments were surveyed.

In the survey, the context of the wall fragment was first established: its orientation and exposure, details of original construction, and the original use of the building of which the wall fragment was a part. To give a rough sketch of the fragment as it currently stood, basic measurements of wall thickness, width, and height were marked on a plan of the wall; for clarity, rough sketches of elevations were often included, with measurements marked. Then the wall fragment was described, including the shape of the fragment, the number and kind of remaining wall intersections, and the number of original door and window openings still remaining. Lastly, the wall fragment's condition was recorded: any leaning and/or bracing, the presence and extent of basal erosion and coving, and the presence and extent of repair materials. Appended to the survey were copies of past documentation, historic and recent, relating to the construction, stabilization, and maintenance of that wall fragment.

In the General Survey, those wall fragments, or specific areas within a wall fragment, particularly vulnerable to deterioration were identified, as were those parts of a wall fragment critical to its survival. In order of importance, the survival of an adobe wall at Fort Union is a factor of:

- original wall thickness
- orientation and exposure
- wall configuration, bond, and supports, namely T- and L-shaped intersections, fireplace/chimney units, window and door lintels, and bracing
- capping treatments
- shelter coat treatments

And while each wall is different, its type and rate of weathering dictated by its particular microclimate, general conclusions can be drawn about which conditions most threaten a wall. In order of importance, they are shouldering (the erosion of vertical surfaces, such as door or window jambs, to sloping profiles), basal erosion, leaning, and coving. Also, on an uncapped wall or on a wall with a cracked or missing cap, water may penetrate to the interior and cause unforeseeable catastrophic failures and wall collapses.

Priorities for Stabilization and Maintenance

The results of the General Survey indicated that maintenance of the adobe ruins should involve the prioritization of work not just to repair damage, as is done now, but to prevent damage by maintaining elements which increase a wall's stability or shelter it from the weather, such as wall intersections and lintels, fireplaces and chimneys, and capping. Based upon this idea and upon an understanding of how an adobe building weathers, priorities for routine adobe stabilization and maintenance were established as a part of the development project.

Implementation of the Preservation Plan

The implementation of the recommendations began immediately after the completion of the Preservation Plan. The maintenance staff worked in conjunction with National Park Service support functions to brace walls identified in the structural engineer's report, and the author worked with the maintenance staff to reorganize maintenance priorities and implement new standardized documentation procedures.

During the summer of 1996, a pilot implementation project was conducted at Fort Union to carry out the second and third recommendations of the Preservation Plan. In the spring, a range of lime-modified adobe caps had been tested at the Architectural Conservation Laboratory of the University of Pennsylvania by graduate students Mark Goodman and Elisa Del Bono. Based upon their recommendations, the most promising of these modified caps were manufactured, and installed on both test walls and historic walls at Fort Union, along with unmodified, cement-modified, hydraulic lime-modified, and acrylic-modified adobes. Potential shelter coats were also selected, manufactured and applied to adobe test walls.

In the spring of 1997, Bob Hartzler and Jake Barrow returned to Fort Union to analyze the results of the adobe monitoring system as well as the performance of the adobe test walls and the pilot caps and shelter coats. Based upon the analyses, recommendations for the material compositions and application procedures for new caps and shelter coats were made. Funding for a major capping project was secured by the Monument, and the work commenced at the beginning of the 1997 summer.

Project Team. Field supervisor, Anne Oliver; and participants, Robert Hartzler, James Banta, and Linnaea Dix.

Note

- John Wesley Pullman in a letter to the Quartermaster General, USA, 30 June 1873, located in "Correspondence 1861–1891," Fort Union National Monument archives, Watrous, New Mexico.

Anne Oliver is an architectural conservator in private practice; she received an MS in Historic Preservation from the University of Pennsylvania in 1994.

Acknowledgment. The success of the project was a result of the close cooperation between the project members, Superintendent Harry Myers and the Monument administration, and the Monument maintenance staff, including Maintenance Foreman Albert Dominguez, Rudy Mondragon, Teddy Garcia, Wilfred Valencia, Napoleon Duran, and Jose Padilla.

Jerry R. Yarbrough

The University of Pennsylvania Comes to Fort Davis, Texas

In 1992, Fort Davis National Historic Site joined the cooperative agreement with UPenn to develop processes for stabilization of historic paints and lime plasters on adobe walls.

Fort Davis has a wealth of original 19th-century painted surfaces, now over 100 years old. Preserving them has become one of our highest priorities. The Southwest Cultural Resources Center aided us in developing and administrating this agreement. The agreement provided for the establishment of a conservation field school program specifically designed for Fort Davis. The intent of the effort was to spend time and energy preserving the authentic historic fabric rather than doing reconstruction or restoration projects.

The program continued for three years until 1994. During the last year of the field school the students camped on site in the renovated rustic non-historic barracks in the canyon behind the fort. The field school helped generate interest in repairing this facility and the park has since used it extensively.

The students working as volunteers stabilized interior paints and lime plasters as well as some exterior exposed plasters on ruins. After the program officially ended, the park arranged for additional field work to continue the effort "in house." In 1996 a team was organized including two UPenn graduates, one student, and two park employees. This constituted an intensive "hands on" training exercise for the park and now we have internalized the plaster stabilization process. We continued the activity and training in 1997.

Before the UPenn program was developed, the park used a generic program for plaster stabilization developed in the 1960s and 1970s. During this time most of the plaster repair work was not performed by park staff. The experience has helped our staff understand, accomplish, administer, and record the processes used by UPenn students. From a park perspective, this program is a great beginning, and has contributed significantly to the preservation of valuable park resources.

Jerry R. Yarbrough is Superintendent of Fort Davis National Historic Site.

Fort Davis National Historic Site; 1886 view of the military post with two-story officers' quarters in foreground, officers' row on right, and enlisted men's barracks on left. Courtesy NPS.

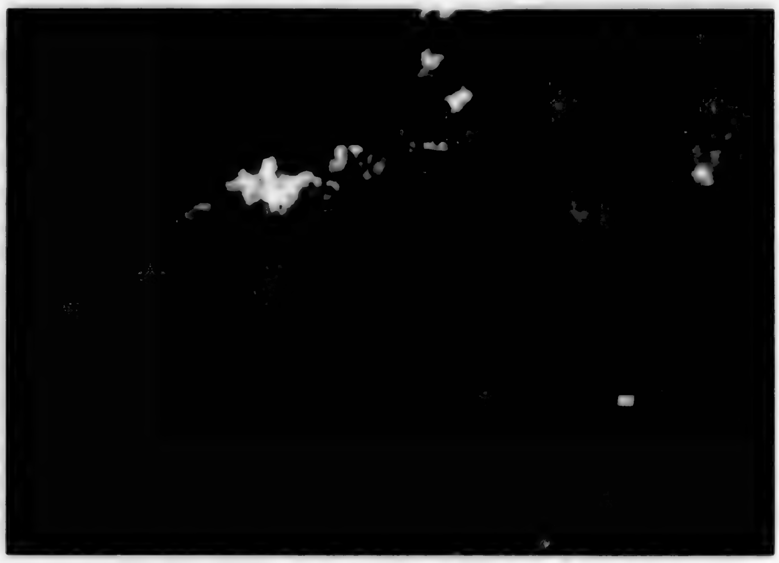
Bob Hartzler

Saving Authentic Surfaces

Plaster and Paint Stabilization at Fort Davis

Fort Davis was abandoned by the U.S. Army in 1891 but never truly abandoned by the residents of West Texas; many of the buildings continued to be used by local ranchers, settlers, and entrepreneurs into the middle of the 20th century. These remnants of the second Fort Davis, begun in 1867, make up one of the most complete 19th-century forts in the American Southwest. When the Fort was acquired by the National Park Service in 1962, the NPS began to stabilize and repair the buildings of the fort which were still largely intact.

Most of the historic structures at Fort Davis can be divided into three general categories: walled structures (stone and adobe) with reconstructed roofs, partially walled structures (adobe) without roofs, and masonry foundations. The presence of roofs on some of the buildings is significant, for the roofs offer structural stability as well as protection from the weather. Adobe walls as well as internal plasters and paints in covered structures are better preserved than those exposed to the precipitation, wind, and sun.



Repairing plasters on adobe walls of the Fort Davis chapel. Photo by the author.

Interior wall plasters and their decorative painted finishes survive to a great degree at Fort Davis despite their vulnerability to weather. Wooden elements in the form of interior millwork (e.g., enframements, moldings, etc.) and some structural framing (floor joists for example) survive in conjunction with the masonry. Paints and decorative schemes typical of the late-19th century are evident in nearly all of the buildings, but especially in the houses on Officers' Row. The high quality and excellent survival of these finishes argue strongly for their conservation.

Field Schools

The first field school participants at Fort Davis in 1992 focused primarily on Historic Building 12 (HB-12), a typical adobe structure in Officers' Row protected by the earlier installation of a wood frame and shingle roof. HB-12 was selected because its representative painted plaster and woodwork retained a high degree of integrity, and because of recent plaster losses. Two rooms with relatively plain non-decorative painted finishes were selected for this first phase of treatment; rooms with more complex painted finishes were reserved for the following years.

The field schools continued in 1993 and 1994. The emphasis in 1993 again was the conservation of the painted finishes in HB-12, and plaster stabilization on the adobe ruin of the Hospital Steward's Quarters. In 1994, work continued on the painted finishes of HB-12, and plaster stabilization and repair at the Post Chapel, a stabilized adobe ruin. The Chapel has only one major remaining historic wall, spanning the width of the building, but nearly all of that wall, from the missing floor to the missing roof, is covered with original lime plaster.

No field school was held in 1995 at Fort Davis, but in 1996 a small team composed of field school graduates and a graduate student returned to Fort Davis, and working with the Fort's Maintenance Foreman and a Maintenance Technician, completed the plaster stabilization work at the Post Chapel. This was a significant development, because it represented another step in the transfer of skills and knowledge from an external resource to an internal, National Park Service team. Now, the maintenance staff at Fort

Davis has the necessary skills to perform emergency plaster stabilization and is better able to assess the condition of the remaining historic plasters.

Treatments

Treatments at Fort Davis included paint consolidation on plaster and wood surfaces, reattachment of detaching plaster fragments, and cleaning and replacement of previous repairs.

Prior to treatment, the condition of each wall or fragment was recorded graphically on a Mylar overlay on a photographic image and through a written conditions report on prepared survey forms. Documentation of previous treatments and repairs was assembled using park records. Photographs were taken before and after treatment, and a written treatment report was prepared for each wall or fragment.

Conservation of Surface Finishes

The interior distemper paints proved to be sensitive to water and mechanical abrasion. Since the removal of soiling and the implementation of the plaster stabilization treatments all resulted in both slight abrasion and wetting of the finished surfaces, it was necessary to first consolidate them before the underlying plaster fragment could be treated. The surfaces were carefully cleaned, and then an acrylic consolidant dissolved in solvent was brushed on through a layer of a wet-strength tissue. After drying, a second and third application was applied in the same manner. This treatment re-adhered the powdering paint without causing any change in surface texture or optical quality and allowed grouting to proceed without danger of staining or disrupting the finishes.

Conservation of Plastered Surfaces

Detaching historic interior lime plaster was re-adhered to the adobe substrate with hydraulic lime-based grout. First, the areas of detachment were mapped. Then, the grout was injected into voids between the plaster and the adobe through cracks or existing holes where possible, or through small holes drilled into the plaster to provide access.

Previously applied cementitious edging was removed from the plaster fragments, except in cases where removal would seriously compromise the historic plaster. It was replaced with more sympathetic material made of hydrated hydraulic lime and sand. Deep losses within the plaster body were filled with edging material and recessed approximately 1/8" below the fragment surface. Shallow fills and open cracks were filled with a mixture of one part hydrated hydraulic lime and three parts fine silica sand.

Plaster reattachment and paint consolidation in HB-12, Fort Davis. Photo by Jake Barrow.

Conclusion

Much work remains at Fort Davis, but through a combination of field schools and NPS expertise, plaster and paint stabilization will continue. The proven techniques described above will continue to be modified and improved, through programs of careful research, field trials, and ongoing site assessment. This approach of collaborative research, treatment, analysis, and documentation can be a model for other important cultural heritage sites with related problems.

Bob Hartzler is an architectural conservator at Fort Union National Monument, and has an MS in Historic Preservation from the University of Pennsylvania.

Rosalind Z. Rock

A Tale of Two Conservation Projects at Mission San Jose, San Antonio

Restoration of Convento drainage system. Photo by Angelyn Bass.

From the outset, San Antonio Missions National Historical Park has been a model to others of the viability of partnerships of various entities, both in and out of the National Park Service. Its very existence is due to partnerships. By means of a series of cooperative agreements with the Archdiocese of San Antonio, the San Antonio Conservation Society, the San Antonio River Authority, the City of San Antonio, Bexar County, and the State of Texas, to name a few, this single largest National Historical Park devoted to Spanish Colonial missions was able to become a reality.[1]

As a precursor to the conservation projects at Mission San Jose described in this issue, a cooperative effort involving the park, the Cultural Resource Center, the United States National Committee of the International Council of Monuments and Sites (US/ICOMOS), and the International Center for the Study of the Preservation and Restoration of Cultural Property (ICCROM) focused their work on the conventos at missions Concepcion and San Jose. The project was funded by the park's friends group, Los Compadres de San Antonio Missions National Historical Park.[2] The main focus of the project was the wall and ceiling decoration in the library of the convento at Concepcion, often referred to as "The Eye of God Room" because of the then partially visible face located in the center of the barrel vault. This room comprises the most complete interior space containing Spanish Colonial era wall decoration in the park.

The field conservation began on July 18 and ended August 18, 1988. The first two weeks were spent primarily working in the library at Concepcion, with this work continuing as efforts also began at the convento of San Jose. The results, especially at Concepcion, were astounding. No longer does only an eye appear as the predominant element in the remnant of the ceiling image. The bearded face of a mestizo surrounded by the rays of the sun appears jewel-like amidst fragments of striping which originally led from it across the length of the barrel vault in both directions. After years of deterioration, the flowers and other shapes remaining from what must have been a rich array of decoration also blossomed forth on the walls.

The more recent conservation involved a deteriorated limestone column which had been part of a 19th-century renovation of the convento at Mission San Jose by Benedictines from Latrobe, Pennsylvania, who wished to establish a school for boys at the site. Funded by Los Compadres, the column conservation was carried out through the cooperative agreement of the University of Pennsylvania and NPS and was funded by both the park's friends group and a grant from the Marcia and Otto Koehler Foundation.[3]

UPenn and the Cultural Resource Center carried out joint research, training, and treatment for the conservation of this weathered sandy limestone column at the convento (see Oliver, page 21). It began in January and ended in May of 1993.[4] Training components consisted of on-site participation by team members and presentations at the midpoint and conclusion of the project to Park Service personnel, Los Compadres, the Koehler Foundation, the local chapter of the American Institute of Architects, and other interested parties.

The convento to which the Benedictines applied their renovation was constructed in the 1770s. By the 1820s the mission appeared largely

Mission San Jose
Photo by Jake Barrow

abandoned and by the 1850s was a ruin subject to the attentions of early photographers. The renovation efforts following shortly thereafter, especially in the convento, retained the northern and southernmost walls of the two-story structure extending east from the church. The remaining internal partition walls were demolished and replaced. Many of the new elements were rubble laid in lime mortar, with the exception of the brick voussoirs of the lancet arch openings and the carved, octagonal, limestone drums of the column on the second story of the east-west interior wall which was the focus of this 1993 conservation project.[5]

In the 1920s, with the beginning of a concerted effort at conservation and rehabilitation of the entire mission site, the first of several attempts at patching the column was carried out. Patching of the column was done again in the 1960s. The latter was of lime and sand, and overlay the earlier gypsum patches and the original gypsum bedding mortar.[6] Beginning in 1987, the Park began monitoring the rapid deterioration of the column. This led to the project to conserve it which began in March 1993.[7]

In 1994 a Paint and Plaster Conservation Project was undertaken cooperatively by the Cultural Resource Center and UPenn. This project entailed the documentation, cleaning, and stabilization of fragments of historic lime plaster in the convento of Mission San Jose. This was part of a larger effort coordinated with the Park to conserve and stabilize the ruins of the convento. The conservation plaster team was under the field supervision of Angelyn Bass. The other, related conservation work was carried out jointly by personnel from the Park and the CRC.[8] (see Bass/Barrow, page 24).

The paint and plaster portion of the project was part of a comprehensive multi-year effort at Mission San Jose initiated by the Park and CRC. Conservation approaches began in 1973 when David Battle, NPS historical architect, and Georgio Torraca from ICCROM visited San Jose and the other missions now included in the Park. They served as consultants on preservation strategies, and as advisors for onsite conservation of significant architectural features. As a consequence of Torraca's recommendations, and other input from NPS professionals, the NPS began a preservation program to institute routine preservation monitoring and maintenance, intensive historic research, and building materials analysis, and to carry out special projects at each of the Park's four mission sites including those described in this issue.

The plaster remnants in the convento date from the 1770s. They are all that remain of what once may have been a fully plastered and decorated interior. Before conservation, the painted plaster fragments were covered with biological growth and hardly visible from the ground floor. They were also extremely fragile. Painted finishes were faded and powdering, whitewash layers were delaminating, and entire portions of fragments were detaching from the wall surface.[9]

In January 1994, Jake Barrow and Angelyn Bass of NPS; Frank Matero of UPenn; and Constance Silver, a private murals conservator and consultant, began researching methods of cleaning and stabilizing the historic convento plasters. Sampling and laboratory investigation of those plasters began in January 1994. Compliance with Section 106 of the National Historic Preservation Act was approved on March 18, and field treatments were carried out March 22–May 10 and November 29–30, 1994.[10]

This extensive work resulted in the identification of 27 historic lime plaster fragments in the sacristy and convento area, 17 of which were fully documented and treated. The fragments that received treatments are located on the interior north wall of the convento. Like the other projects presented here, the Park's friends group, Los Compadres, provided the funding.[11] These conservation projects helped save elements of the historic mission sites within the Park which would otherwise have deteriorated to the point of loss. None of these would have been able to be carried out, especially in this time of tight budgets and downsizing, without the generosity, and the cooperative ventures of UPenn and the Cultural Resource divisions within the NPS. Amidst such partnerships, San

Antonio Missions National Historical Park continues to thrive.

Notes

[1] San Antonio Missions National Historical Park, General Management Plan/Development Concept Plan (Santa Fe, New Mexico: Southwest Regional Office, National Park Service, July 1982), 98.

[2] Denver Service Center, National Park Service, "San Antonio Missions National Historical Park—1988 Conservation Project Completion Report, Draft," April 1997, viii.

[3] Anne Brackin, "A Comparative Study of the Effects of Applying Acrylics and Silanes in Sequence and in Mixture, with a Case Study of the Column in the Convento of Mission San Jose y San Miguel de Aguayo, Texas" (MS thesis, University of Pennsylvania, 1994), 96.

[4] Brackin, "A Comparative Study," 96-97.

[5] Brackin, "A Comparative Study," 98-99.

[6] Brackin, "A Comparative Study," 99.

[7] Brackin, "A Comparative Study", 99.

[8] Angelyn Bass, Robert Rivera, and Jake Barrow, "Mission San Jose y San Miguel de Aguayo Plaster and Paint Conservation Project, San Antonio Missions National Historical Park—Conservation Treatment Report" (Santa Fe: National Park Service, Southwest Regional Office, December 1994), 1.0, "Project Summary."

[9] Bass, Rivera, and Barrow "Plaster and Paint Conservation Project," 1.0, "Project Summary."

[10] Bass, Rivera, and Barrow "Plaster and Paint Conservation Project," 1.0, "Project Summary."

[11] Bass, Rivera, and Barrow "Plaster and Paint Conservation Project," 1.0, "Project Summary."

Rosalind Z. Rock, Ph.D., is park historian, San Antonio Missions National Historical Park.

Anne Oliver

Stability and Integrity
The Convento Stone Column at Mission San Jose

Column before restoration, 1992.

Mission San Jose y San Miguel de Aguayo is one of four Spanish missions administered by San Antonio Missions National Historical Park, Texas. The mission was founded in 1721 by Franciscan brothers from Zacatecas, in New Spain (now Mexico). A series of buildings was erected to house the activities of the mission through the years, and in the 1770s an extensive rebuilding program was undertaken, resulting in many of the elements of the church and convento complex standing today. The rubblestone walls of the new buildings were constructed mainly of local tufa and limestone laid in a lime mortar; carved elements, including the facade and the sacristy window, were sculpted of a softer and more compact white chalk limestone.

By the 1820s, the mission was nearly abandoned, and by the 1850s was considered a picturesque ruin by tourists and photographers. But in 1861, the church and convento were reinhabited by brothers of the Benedictine order, and a second major rebuilding program was begun. In the convento, the exterior walls of the two-story structure were retained, but the internal partition walls were demolished and replaced. All of the new masonry was laid in lime mortar, with the exception of the drums of an octagonal column, which were laid in gypsum mortar. These rebuilt elements of the convento were meant to serve as interior spaces, with the column accenting the second story of a stair hall; however, in 1868 the

Column condition before restoration, detail, 1992.

Benedictines were forced to abandon the site, and the convento was never roofed.

Following the efforts of the Benedictines, the mission complex was again abandoned until the 1920s, when renewed interest in all of the San Antonio missions resulted in extensive archeology, reconstruction, and maintenance of the structures. The convento of Mission San Jose was stabilized, and the column bears the evidence of two repair campaigns. The first is revealed in a photograph from around 1927 in which large white patches are visible; these match the locations of the present-day gypsum patches. The second set of repairs was applied at an undetermined later date, and appear in photographs dating from the 1960s; these are of lime and sand, and overlay the earlier gypsum patches and original gypsum bedding mortar.

Gypsum is a solubile salt; in the presence of water it will move into solution and permeate the pores of the stone. As the water evaporates, the gypsum recrystallizes and exerts pressure on the pores, causing microcracking and flaking which will eventually destroy the stone. On the column, the most severe levels of deterioration were immediately beneath and adjacent to the gypsum bedding mortar and patches; stone in these areas was very friable to the touch and exhibited the extensive microcracking and flaking typical of salt-contaminated stone. In contrast, areas of the column were very sound where little or no gypsum had been used.

Since 1987, the National Park Service had monitored the deterioration of the column in the convento. Its increasingly critical condition spurred the development of a joint research, training, and treatment project by the Southwest Regional Office of the National Park Service and the Architectural Conservation Laboratory of the University of Pennsylvania in 1993.

Applying consolidant to column surface. HS203A-North wall, 1993.

A literature review revealed that mixtures of acrylics and alkyl alkoxysilanes are frequently and successfully used for the conservation of friable and flaking stone. These mixtures combine the consolidative and adhesive properties of acrylics and the consolidative and water-repellent properties of alkyl alkoxysilanes. Although not perfect, mixtures often satisfy more of the commonly recognized criteria for stone consolidants than any other treatment.

But levels of deterioration varied on the column. While the application of a mixture of acrylic and silane would consolidate the severely deteriorated areas, the acrylic would also negatively alter the properties of relatively sound areas. Massive losses of stone in certain areas also dictated the use of infills to re-establish the structural and visual integrity of the column; the water-repellent properties of the silane in the mixture would inhibit the adhesion of these fills. However, the sequential application of the same materials would allow for flexibility in treating different levels of deterioration and for the adhesion of infills.

(Right) Post-treatment evaluation of column by Jake Barrow. Photo by Angelyn Bass.

The relative effectiveness of this sequential method of application was not well-studied; thus a pretreatment experimental program was designed and conducted at the Architectural Conservation Laboratory to compare the differences in the effects of sequential applications and mixtures on the physical and mechanical properties of the stone. In the test results, mixtures proved somewhat more effective than sequential applications because they exhibited a greater depth of penetration and retention of acrylic and silane. However, there were no significant differences in water absorption, water vapor transmission, color change, or resistance to salt crystallization.

Because of the localized deterioration patterns on the column, and because of the need to apply fills to reestablish structural and visual integrity, the benefits of a sequential treatment program outweighed the disadvantages. Thus a sequential treatment program was implemented to conserve the column.

Column after conservation.

Routine maintenance inspections of the column, made in 1993 and 1996, reveal no further loss of material, no additional accumulation of salts, and continued good adhesion of fills.

Funding for the project was provided by the friends' group, Los Compadres de San Antonio Missions National Historical Park, which secured a grant from the Marcia and Otto Koehler Foundation. Training components included on-site participation by team members and presentations at the midpoint and conclusion of the project to members of the National Park Service, Los Compadres de San Antonio Missions National Historical Park, the Koehler Foundation, the local chapter of the American Institute of Architects, and others. Team members have since applied the methodology and treatments to projects both within and outside of the National Park Service system.

Project Team. **Field supervisor, Anne Brackin Oliver; and project participants Keith Newlin (NPS, Denver Service Center) and Diana Motiejuanaite (NPS, ICOMOS intern).**

Anne Oliver is an architectural conservator in private practice; she received an MS in Historic Preservation from the University of Pennsylvania in 1994.

Photos by Jake Barrow.

Angelyn Bass and Jake Barrow

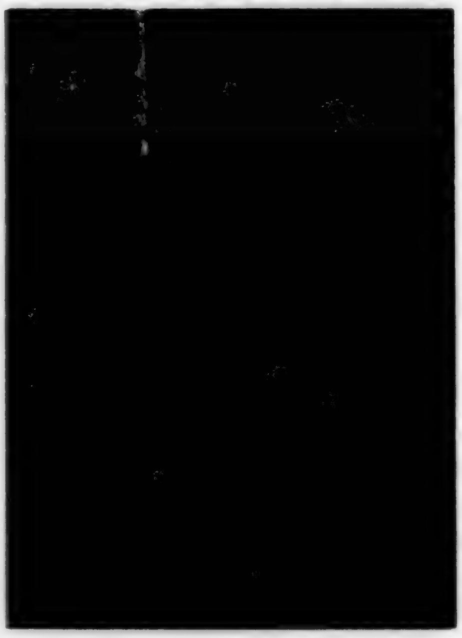
18th-Century Plasters Preserved

Conservation in the Convento of Mission San Jose

As conservators worked on scaffolding set high in the second floor ruins of the convento of Mission San Jose, they would often pause from their work to watch people below gather for the daily church service, or listen to a Mariachi band play for a celebration, or even just look out over the Mission grounds to imagine what life there must have been like centuries ago. It was common to feel awestruck by the Mission's beauty and by the continuity of tradition that has survived there since the 18th century.

The history of the Mission spans three centuries, with architectural fabric from every period in evidence. These significant vestiges of historic fabric are among the few remaining examples of original colonial mission architecture in the Southwest. Among the earliest artifacts at the Mission dating from the Franciscan occupation in the mid- to late-18th century are fragments of painted lime plaster in the convento.

Constance Silver and Frank Matero developing procedures to treat San Jose Convento plasters.



In January 1994, the NPS implemented the Plaster Conservation Project to clean and stabilize the plaster fragments on the north convento wall and to reduce the causes of their deterioration. The project took place in three phases: Phase I involved assessment of condition and deterioration mechanisms; Phase II was conservation treatment; and Phase III was treatment assessment and design and implementation of a maintenance and monitoring plan.

The conservation project was a collaboration between NPS and UPenn, private conservators, and staff of San Antonio Missions National Historical Park. As a result, 17 plaster fragments, some with incised and painted decoration, were documented and conserved *in situ*. In addition to plaster conservation and integral to its success were associated efforts to repoint deteriorated stone masonry, to redirect the wall capping to channel rain water run-off away from the plaster fragments, and to modify drainage systems to divert water away from the base of the masonry walls. The project also involved training NPS personnel and private sector preservation professionals.

The Convento Plasters

Mission San Jose was founded in the 1740s by the Franciscan brothers of the College of Zacatecas, Mexico. The church and principal buildings of San Jose, including the convento, were constructed of local materials: sandstone, tufa, and limestone set in a lime mortar, and the walls were once elaborately decorated with stone carving and painted plasters. Though only faint traces of the painted designs are still visible, abundant archival information exists attesting to the original colorful painted facade of the church and the interior of the convento.[1] The typical decorative motifs seen in the convento are geometric patterns (with incised preparatory drawing) and some free-hand floral designs.

The convento is a ruined structure, two stories high and divided into four-room units connected by arched doorways. It does not have a roof; consequently, the masonry walls and plaster fragments are directly exposed to the open environment.

The Conservation Project

Condition assessment

Assessment of the plaster fragments in 1994 prior to treatment revealed them to be in a generally poor and fragile state. Most fragments were covered with lichens, and marked by black streaks that followed the path of water run-off. The plasters were barely visible from the ground floor and the painted decorations were virtually indiscernible. In addition, large areas of plaster were detached from the masonry support, layers of limewash had delaminated, and the painted finishes had disintegrated and were powdery to the touch.

Water was a principal agent of deterioration, having flowed over the walls and washing away surface particles. This resulted in undercutting plaster edges and eventual loss of some fragments. Water vapor from high relative humidity in combination with the wall's southern exposure contributed to the propagation of microflora, which by their physiology, chemically and mechanically damage the plaster surface. Microscopic examination of plaster samples showed lichen hyphae had penetrated to 1mm beneath the surface.

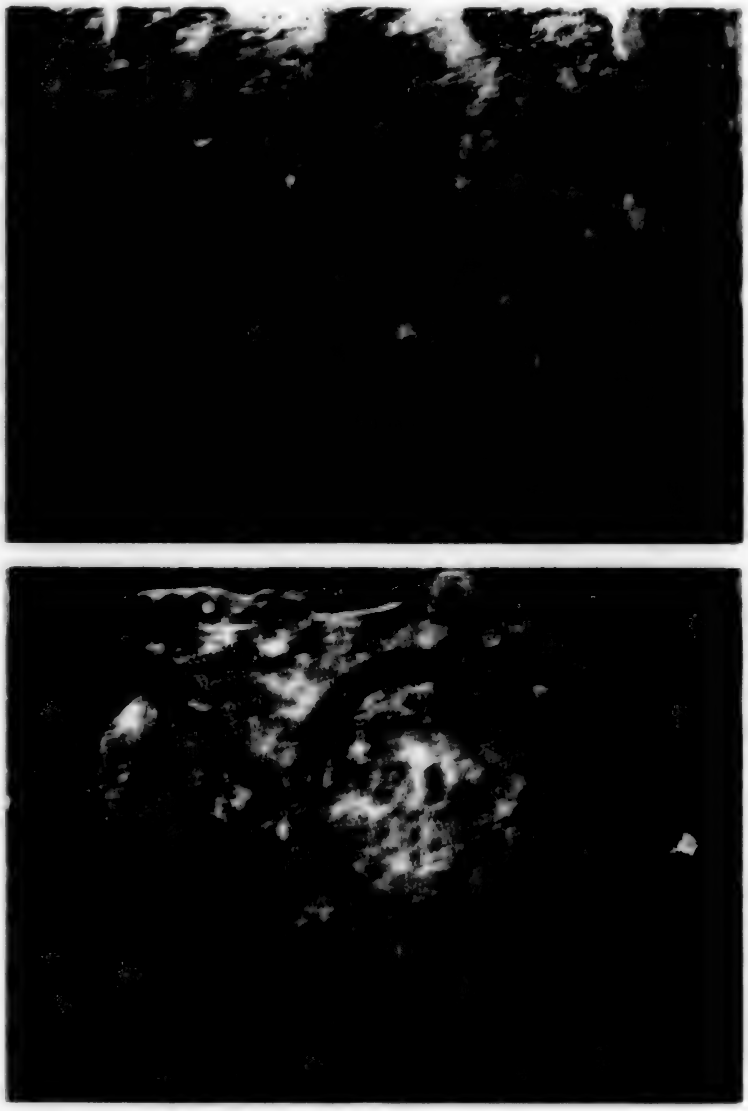
Materials analysis

The plasters in the convento at San Jose are made of lime and a composite aggregate, at an approximate ratio of 1:3.[2] Examination of the samples under the microscope revealed a three layer plaster system, with a thick, single coat of plaster applied directly on the masonry, and at least two campaigns of painted designs, separated by multiple layers of limewash.

The painting technique appears to be fresco seco (painted on a dry ground) and the principal color preserved is red, with faint traces of yellow and blue. The red pigment tested positive for iron in microchemical spot tests, indicating the use of iron oxide. Instrumental analysis of the paint's binding media proved negative for the presence of organic material, including casein, glue, oil, and gum.[3]

Documentation

Prior to intervention, each plaster fragment was numbered and sketched on an elevation drawing. Field notes were taken describing the techniques of execution, state of conservation, and treatments. Before and after conservation work, 35mm photographs were taken. When available, historic photos were used to evaluate and measure extent of change.



San Antonio Missions NHP, Mission San Jose paint and plaster conservation project. Room #HS203-C, Fragments: 198 before and after treatment.

Cleaning

Partial removal of the biological growth was conducted to abate the destructive mechanism and to make the fragments visible from the ground floor. A combination of dry and wet methods were first tested on plaster facsimiles and then on small unpainted plaster fragments *in situ* before being applied to the larger fragments. Prior to cleaning, the painted finishes were pre-consolidated with an acrylic resin solution which fixed the paint without bonding the biological organisms and dirt.

The dry cleaning method involved gently rubbing the encrusted surface with small natural bristle stencil brushes. On unpainted surfaces, dry cleaning was followed by wet cleaning with a weak bleaching agent to discolor the subsurface hyphae. Painted areas were not wet cleaned. Afterward, the treated areas were rinsed with water and dabbed dry with cotton.

Removal of previous repairs and stabilization

Most of the plaster fragments had been previously stabilized with lime and cement based mixtures. In order to access and fill voids behind the surface and to replace inappropriate fills, the previous repairs were removed by hand with a narrow-tipped chisel. When plaster edges were fragile or delaminating, they were temporarily stabilized with facings adhered with a dilute water soluble adhesive.

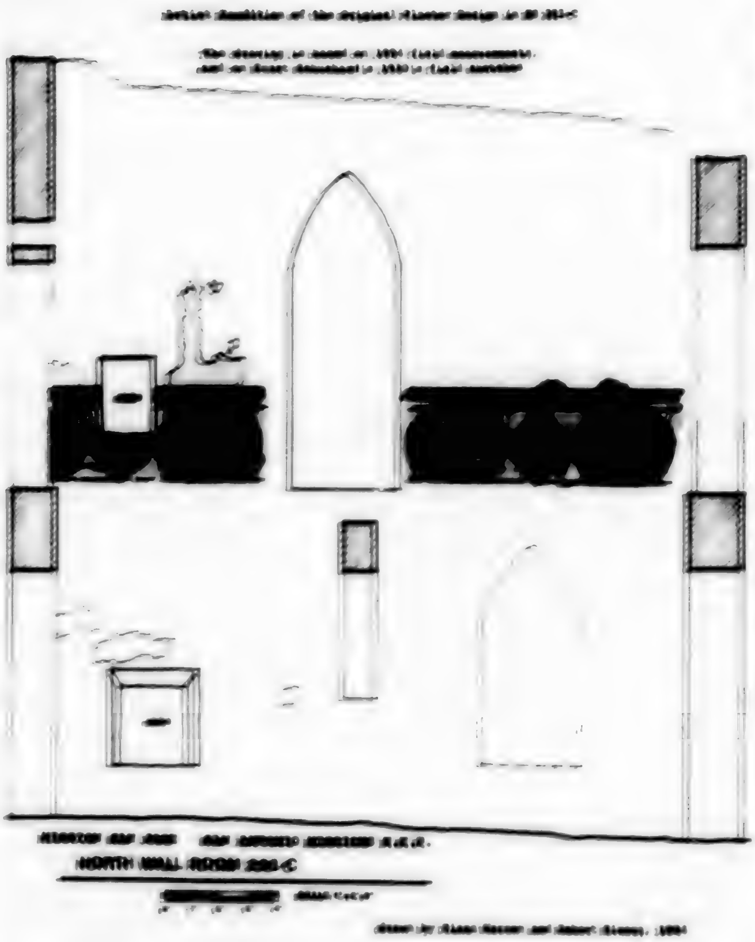
Following removal of repairs, voids were grouted with a hydraulic lime mixture injected through a syringe. A hydraulic lime grout was chosen because of its physico-chemical and mechanical compatibility with the historic fabric and because of reported favorable results when used to re-adhere plaster in similar exposed conditions.[4] After grouting, when it was apparent that the fragile areas were stable, the temporary facings were removed with water.

Re-adhesion of delaminating limewash

Re-adhesion of localized areas of delaminated limewash (without paint) was conducted by injecting a dilute acrylic emulsion between the separated layers. The treated area was lightly compressed by hand with a layer of Japanese tissue and bulk cotton and held in place until the area was stable. The localized pressure served to compact the strata and restore cohesive strength.

Edging and filling

Following cleaning and stabilization, losses, cracks, and exposed edges were filled with a hydraulic lime mortar to protect them from water ingress. Surface losses within fragments were filled with the fine-grained mix. The fills were recessed slightly lower than the original surface, rendering them distinguishable. Edges were sculpted at a slight angle with a coarse grained mix to positively shed water away from the plaster surface.


Artist's Rendition of the Original Plaster Design in HS 203-C
NORTH WALL ROOM 203-C
Drawn by Diana Warren and Robert Rivera, 1994

Mission San Jose, San Antonio Missions NHP. Artist's rendition of the original plaster design in HS 203-C. The drawing is based on 1994 field measurements, and on Ernst Schuchard's 1930s field sketches. Drawn by Diana Warren and Robert Rivera, 1994.

Application of water repellent

Four months after repairs had time to cure, a silane water repellent was applied to the surface for protection from liquid water and to retard biological growth. Silanes, in particular the alkoxysilanes, were chosen for use as a water repellent because their molecules are small enough to penetrate the plaster substrate, react, and leave a deposit of amorphous silica within the plaster pores. This siliceous deposition gives the plaster a non-polar aspect, which causes water to repel rather than accumulate in the pores.[5]

Final report

At the conclusion of the work a report was submitted to the Park providing textual and photographic documentation of the conservation treatments, including results of pre-treatment investigations and testing; maps and drawings of the convento and the plaster fragments; and recommendations for future conservation treatments.

Dry cleaning lichen on painted plasters.

Photos by Angelyn Bass.

In the spring of 1996, two years after the conservation work, an evaluation of the plasters revealed that they were in stable condition: the fragments were well adhered; the edging and infill repairs were intact; and there was little to no evidence of new biological growth.

Also during that time, a maintenance and monitoring plan for the plasters was field tested and presented to the Park for inclusion in their maintenance program. Ultimately, the success of the conservation depends on continued management and control of the deteriorating factors.

Project Team. Field supervisor, Angelyn Bass; and participants Diana Warren, Armando Criollo, Anne Oliver, Sharon Fleming, and Constance Silver. Victor Marin (CNCRM) joined the team from Cuba.

Notes

[1] Ivey, James E., Thurber, Marlys B., and Escobedo, Santiago. Of Various Magnificence: The Architectural History of the San Antonio Missions in the Colonial Period and in the Nineteenth Century. Volume I. *Professional Papers No. 11*. (Santa Fe, New Mexico: 1990.)

[2] Ratio of lime to aggregate was determined by acid dissolution in HCL and gravimetry. The composition and type of aggregate is the same as the masonry bedding mortar.

[3] Binder analysis using fluorescence microscopy and Fourier transform infrared (FTIR) microanalysis was conducted by Catherine Myers, Curator of Paintings and Architectural Materials, in March 1994. The negative results do not necessarily prove that organic binders were not used. It is possible that the binder has since degraded or was undetectable using these analytical techniques.

[4] Matero, Frank, and Bass, Angelyn. "Orphans of the storm: the preservation of architectural plasters in earthen ruins," in CRM, Volume 17, Number 4, 1994.

[5] Weber, Helmut, and Zinsmeister, Klaus. *The Conservation of Natural Stone: Guidelines to Consolidation, Restoration and Preservation.* (Ehningen: Expert-Verlag, 1991.)

Angelyn Bass is an architectural conservator. Jake Barrow is guest co-editor of this issue.

Acknowledgment. Thanks to SAAN Superintendent Steve Whitesell and former Superintendent Bob Amdor, Catherine Myers, Jake Ivey, Mark Chavez, and James Oliver. Special appreciation to Los Compadres for their support.

John Lujan

Inscription Preservation

A Challenge Met at El Morro

The reorganization of the National Park Service has opened eyes, turned heads, and brought sighs of relief and frowns of exasperation. Reorganization has prompted us to look back, look forward, and look deep inside. Critical analysis of our institutions can often be gut-wrenching. However, if taken with the best interest of the organization in mind, it can be quite rewarding. One of the many rewarding features of reorganizing has been our renewed effort at establishing and nurturing partnerships. Not that partnerships are new; rather, we are beginning to look at them in a new way. We are now looking at partnerships from the perspective that they provide information and resources to augment existing management tools.

In 1993, El Morro National Monument entered into a cooperative agreement with UPenn to develop treatment options for deteriorating historic inscriptions. The focus of the research was intended to give El Morro managers critical information necessary for the conservation and preservation of fragile, at risk inscriptions. The goal of our preservation effort is not to reverse deterioration or stop it but to manage it and slow it down. This concept was mutually agreed upon through our consultation with the Zuni Tribe who are significant stakeholders in the site.

I owe a debt of gratitude to my predecessors, Reed Detring, who re-emphasized the need to focus on inscription preservation and, later, Michelle Pelletier, who got the program up and running. Michelle secured funding to initiate the project, and oversaw the first stage documentation and research and coordinated the Zuni consultations.

The problem of deteriorating inscriptions and how best to protect them is not a recent phenomenon. Preservation treatments of one kind or another have been attempted at El Morro since the mid-1920s. So what are we doing that's different? Partnering!

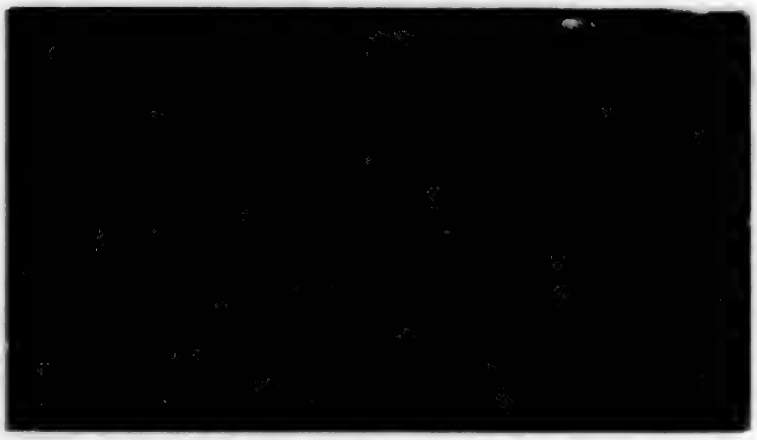
After the first phase of documentation and preliminary condition survey was accomplished "in house" and by contract, we used the cooperative agreement with UPenn to bring together a number of talented individuals from a variety of disciplines and agencies. The activities accomplished were outside our "normal" sphere of abilities. Archeologists and conservators, using historic and modern photographs, determined critical areas needing treatment.

Using information gathered by the specialists, resources management personnel were able to construct a customized database which serves as baseline documentation and a guide for monitoring and research activities. Focusing on the parameters established by the priority rating system, inscriptions with the highest potential for deterioration and loss can be readily identified and targeted for treatment (see Padgett and Barthuli, page 28). In order for conservators to initiate treatment strategies, an understanding of the basic geological concepts and process that formed El Morro was needed. The Park hired a geologist to perform this task and in the process we learned a tremendous amount of new information about our resource. We started to interpret the geology as well as the inscriptions (see Cross, page 30).

In July of 1996, with documentation complete, a geologic study underway, lab research accomplished, and one pilot test season over, a team including the University of Pennsylvania conservators and NPS personnel re-attached to the cliff face a rock slab containing historic inscriptions. Also, separating and dissolving stone was re-adhered and consolidated. These uncelebrated events marked the culmination of years of research, hard work, and teamwork.

Is this the beginning or the end? As natural processes continue to take their toll on the historic inscriptions of El Morro, the need to understand and mitigate those processes will continue. Through the efforts of some incredibly dedicated, hard working individuals, a giant step forward has been taken. Management's decision to step forward is not always an easy one. However, well established, tested, and documented methods make those decisions much easier. I offer my sincerest thanks to those who have made my journey just a little easier. I look forward to strengthening our partnerships and new efforts contributing to the preservation of El Morro.

John Lujan is the Superintendent of El Morro National Monument.



Aerial view of El Morro National Monument. NPS photo.

Antoinette Padgett and Kaisa Barthuli

Rock Art Documentation and Assessment

El Morro National Monument, located near the Pueblo of Zuni, New Mexico, is best known for Inscription Rock. This 200' sandstone outcrop chronicles the passage of people through that part of the Southwest for hundreds of years. A natural pool, nestled at the base of the rock, attracted many of those who passed by.

Near the pool, along the base of the rock, are petroglyphs of prehistoric Puebloan people, and names and dates of Spanish explorers, Anglo settlers, and survey expeditions, along with more recent "graffiti." Many of the historic names and prehistoric drawings on the rock have been, and are being, obliterated due to the deterioration of the sandstone by both natural and human induced factors.

A pilot project was undertaken by the National Park Service in 1992 to assess the causes of deterioration of the inscriptions and rock art at El Morro National Monument and to make recommendations for their preservation. (Padgett 1992; Padgett and Bartuli 1996). First, a comprehensive bibliography of past documentation was compiled. Next, physical examination of the inscriptions and rock art was conducted to determine the extent and primary causes of deterioration. Fifty panels were selected to serve as representative examples (a "panel" refers to an area of rock surface containing one or a group of inscriptions). For each of the 50 panels, black and white photographs were taken and enlarged into an 8"x10" format. The photographs were then taken into the field and comparisons were made with existing historic photographs (when available) to assess current condition. Information from these assessments was annotated onto Mylar sheets overlaying the 8"x10" photographs. Colored pens and a color key chart were used to denote different deteriorative factors on the Mylar-photograph assemblage.

Inscription Rock, El Morro National Monument. Photo by Jake Barrow.

A condition assessment form was also completed for each panel. It was determined that the primary, natural deteriorative factors affecting the inscriptions and rock art are clay deposits washing over the rock surface, insect disturbance, salt efflorescence, spalling, instability of the rock surface, and dampness. Human factors include surface abrasion, penciling of the inscriptions for photographic purposes, and inscribed graffiti.

Based on these assessments, recommendations were made for preservation of the inscriptions and rock art at El Morro (Padgett 1992). Recommendations included conducting comprehensive photodocumentation of all inscription and rock art panels; conducting condition and significance assessments to establish a priority rating system for preservation treatment of each panel; developing a long-term monitoring program; investigating a program for testing consolidants; and devising an emergency stabilization treatment program for panels assessed as high priority. Based on recommendations made during the pilot project, over 600 panels were documented and assessed during the subsequent 1993 and 1994 field seasons.

Methodology applied during the 1993 and 1994 field seasons included assigning each panel a section letter and number designation; e.g., "A-1" indicates Section A, Panel 1, a system consistent with, and expanding upon, former numbering systems used at El Morro.

Photographic documentation was conducted by replicating the camera positions used in a past photographic survey (Howell and McNeil 1955), to enable consistent comparisons between photographs. New camera positions were established for inscriptions never before documented. Due to the large number of inscriptions to be recorded, and the finite amount of time to complete the project, a low ASA, high resolution, black and white

35mm film format was chosen over a 4" x 5" format. This compromise in film negative quality was balanced by the speed and agility of using a 35mm camera system. Color slides were also taken of each panel. A perspective control lens was used whenever possible to minimize distortion and enable more precise measurements to be taken directly from the photographs. A 5cm or 10cm scale was placed in each photo when logistically possible. A light reflector disk was used to augment or redirect sunlight when necessary. In areas of perpetual shade, flood lamps were used. Whenever possible, inscriptions were photographed with side-raking light, which was determined to be optimal lighting for highlighting incised inscriptions. Overview photos of sections were also taken. A corresponding Mylar overlay for each overview section photo was developed to show the location of each panel within that section. This information should help future site researchers locate even the most ephemeral panel. All photographs taken were recorded in a photographic log which contained the date, view, and subject for each exposure. An index which references each panel to its corresponding film roll and negative/slide number was also created.

In addition to the photography, a condition assessment form was created to document the particular problems observed at El Morro. The form includes locational information such as panel and section number, orientation, and azimuth. The form also lists a priority rating for each panel (described below); the main agent of deterioration or threat to the panel; the names of the photographers and assessors; the date; and a description of known, past documentation. Inscription elements were sketched onto the form in the same configuration as they appear on the rock face. The dimensions of each element were also measured and recorded. All natural and human induced factors observed to be affecting the panel were then described in detail on the form, and general comments were made. A separate map of all inscription locations was also produced.

Documentation project using reflector to control light on the stone surface. Photo by Antoinette Padgett.

A priority rating system was developed to prioritize panels for monitoring and treatment. The system was devised to examine both the present condition and potential threats for each panel. The numeric point system follows:

Condition. Physical condition of the inscription based on assessment

3 Not stable, extreme deterioration
2 Poor condition, major deterioration apparent, immediate action required
1 Fair condition, minor deterioration apparent
0 Good condition, intact

Threats. Threatening or detectable negative effects on the inscription

3 *Severe*: resource may be significantly damaged or lost if action is not taken within 2 years
2 *Moderate*: damage or loss may occur if action is not taken within 5 years
1 *Low*: continuing effect of impact unknown
0 None observed

A panel with a high numeric designation (combined rating of 5 or 6, or a rating of 3 for either condition or threats) indicates the need for close monitoring. If current research provides a suitable treatment for the major problems at El Morro, the rating system will be useful for determining which panels require immediate attention.

The inscription assessment project was successful in documenting the majority of known inscriptions at El Morro. It was determined that the main agents of deterioration or threats affecting the condition of the panels are in order of greatest magnitude to least: clay wash, unstable rock surfaces, microflora, granular disintegration, spalling, abrasion, microflaking, microspalling of the substrate, microspalling of clay wash, microspalling of pigment, large cracks, partial detachment, insects, and mud deposits.

A computer database was developed to manage the resulting photographic and condition assessment data. Utilizing a photographic data management system produced by Kodak Corp., photographic and assessment data was input into the system and synthesized to enable easy retrieval of information on individual inscription and rock art panels. The system allows researchers and managers to query the database for information such as the number of panels assigned a particular priority rating or the number of panels affected by a particular erosion factor. Future additions to the database may include monitoring and preservation research data. A monitoring program based on the priority rating system has been designed and awaits implementation, and treatment research is currently in progress. The baseline data collected during the assessment will assist managers, researchers, and visitors for decades to come, and will preserve the messages of Inscription Rock in a format that wind and water can never erase.

Project Team. Field supervisors: Antoinette Padgett and Kaisa Barthuli, and participants Pati DeCesaro, Caludia Danninger, Kathy Davis, Jennifer Losee, Tom Poveymirov, Elisa De Bono.

References

Howell, C., and L. McNeil, Jr., Collection of over 230 annotated black and white photographs of inscriptions at El Morro National Monument for the National Park Service, 1955.

Padgett, A. Assessment of deteriorative factors affecting the inscriptions, El Morro National Monument, New Mexico, with recommendations for their preservation, unpublished report to the National Park Service, 45 pp., 1992.

Padgett A., and K. Barthuli, Paso por aqui: A history of site management at El Morro National Monument, New Mexico, USA in G. Ward and L. Ward (eds.), *Proceedings of Symposium H—Management of Rock Art Imagery*, Second International Congress of the Australian Rock Art Research Association, Cairns, Queensland, 1992. Occasional AURA Publication No. 9, AURA Inc., Melbourne, p. 26-33, 1995.

Antoinette Padgett is a consultant specializing in rock art conservation and site management.

Kaisa Barthuli is an Archeology Technician for the Conservation Program, Intermountain Cultural Resource Center.

Acknowledgment. Thanks to Superintendent Reed Detring, Superintendent Michelle Pelletier, Project Manager Mike Taylor (former NPS staff) for their support which made this project possible from the start.

Stephen Aaron Cross

Weathering of the El Morro Inscriptions

El Morro is a large sandstone promontory that rises from a broad, linear valley on the southern margin of New Mexico's Zuni Mountains. The valley is a centuries-old corridor for east-west travel, and the perennial pool of water at the base of El Morro is a customary stop along the way. Many travelers left their marks carved on the bluff, and the historical inscriptions, the oldest dating back to 1605, are the reason for El Morro's national monument status. The inscriptions are weathering at different rates; while some of the older inscriptions are in pristine condition, more recent ones are succumbing to erosion. Deterioration of these engravings is largely controlled by the interplay of extant geological conditions with fluctuating environmental conditions.

The promontory at El Morro is a landform known as a cuesta, an inclined mesa formed by the erosion of tilted strata. One flank is bounded by cliffs, the opposite flank dips gently into the subsurface. The northeast point of this cuesta forms the tallest cliff, and here is also the lowest exposed strata at the base of the outcrop. Along the northern and eastern walls, the strata dips gently into the subsurface.

The El Morro cliffs are composed of the Jurassic Zuni Sandstone, which, like other sandstones, is made of a framework of sand grains, the space between the grains, and any material that may occupy the space, such as fine-grained clay-sized particles or crystalline cement that precipitates from pore fluids. The main constituents of El Morro's Zuni Sandstone are quartz, with a lesser component of feldspars. The grains are remarkably uniform in size and shape, and this provides high original porosity. The re-arrangement and deformation of grains appears to have been minimal, and the intergranular space is largely preserved. Today, most of the space is occupied by either cement or fine-grained matrix.

Iron oxide cements occur in the upper layers of the Zuni, either disseminated in bands and nodules, as pore-filling cement along bounding surfaces, or as surface encrustations known as case

El Morro National Monument. Photo by Jake Barrow.

hardening. (While quartz cements are also common in sandstone, none were found in the Zuni.) Case hardening involves the formation of hard, limonitic crusts along well-established surfaces, and at El Morro it is closely associated with rock joints that apparently provided avenues for iron-rich waters. Chloritic cements occur in restricted stratigraphic horizons below the iron oxide. Throughout much of the Zuni, clay materials are the only form of cement present, hence the general friability of the rock. These clay cements occur as coating on framework grains, which are aggregated by the surface cohesion of the clay. The coatings are found beneath carbonate cement and iron oxide cement, indicating that coatings began forming early in the diagenetic history of the rock. The fine-grained particles in the matrix are mostly kaolinite clay, which is a by-product of the degradation of feldspars. Also present in the fine-grained fraction, in smaller quantities, are chlorite, illite, vermiculite, and mixed-layer illite-smectite. Dissolution features observed in the Zuni Sandstone include oversized pores resulting from grain and cement dissolution and "ghost grains," which are coatings that precipitated on a grain and were left behind when the grain dissolved.

Weathering is the process by which rocks are destroyed at or near the surface of the earth. A variety of weathering processes have been active in El Morro, and these processes threaten the site's inscriptions. Rock destruction is accomplished by chemical and mechanical weathering and by the activities of organisms. Chemical weathering processes involve equilibrium reactions between rocks and the atmosphere and hydrosphere. Such processes account for the oxidization of iron, the degradation of silicate minerals, and the dissolution of cements. Mechanical weathering processes involve contraction and expansion associated with freeze/thaw or wet/dry cycles. Also, when water percolates through permeable sandstone, it becomes enriched in soluble salts that concentrate and crystallize during dry periods. Then, after wet weather, rehydration of the salt causes volume expansion. Minerals that are brought to the rock surface accumulate and form a cap that is harder and less permeable than the underlying sandstone. Salts are repeatedly deposited behind this surface and can eventually cause spalling of the cap. Chemical weathering generally has a more significant impact on rock surfaces than does mechanical weathering. Microflora (lichen, mosses, and algae) can cause both physical and chemical damage to rock surfaces as their roots penetrate rock surfaces and produce oxalic acid that can break down silicates. Microflora can also cause retention of moisture on the outcrop. In each weathering process, water is the major player, whether introduced into the rock as surface wetting, horizontal and vertical percolation, or rising damp.

Material is removed from the outcrop in three principal ways: granular disintegration, wholesale wasting, and spalling. Granular disintegration takes place when material is separated as individual grains or small clumps of grains, and it occurs with the loss of cementing agents within the sandstone. Wholesale wasting occurs when coherent blocks or chunks become detached from the outcrop. This process may be caused by freeze/thaw processes and may be partially controlled by the unloading of inherited strain. Spalling occurs as material is shed as small, relatively thin flakes, chips, or scales, and it is probably caused by the interplay of moisture and the formation of salts.

Comparisons of existing conditions to photographic surveys indicate inscriptions on El Morro's northeast point have eroded most rapidly. Many inscriptions that were visible only a few years ago are partially or completely gone due to granular disintegration. This northeastern site receives extreme exposure to rain and wind-borne particles, and it also carries a concentration of surface and sub-surface drainage. Vegetative differences indicate that soils here retain more water than in the surrounding areas, and no doubt this part of the outcrop is subject to rising damp. Capillary action

Conservation team evaluating stone deterioration along the trail. Photo by Scott Kreilick.

is probably accelerated due to surface drying resulting from windy conditions. Disintegration may be due to the dissolution of clay rims, which are the principal form of cement in this particular strata.

Cove-style weathering features are located along specific bounding surfaces. The coves are probably produced by sapping, a process in which water percolating downward through permeable sandstone encounters a less permeable layer and is deflected outward along this layer to the surface of the rock, carrying soluble cements to the surface where they are washed away.

Further research is required to determine the interplay of environmental factors and the differing strata of rock. Honeycomb weathering is common at El Morro, and it seems to be controlled by both environmental factors and stratigraphic factors — in some areas such weathering occurs across bedding, in other areas it is restricted to certain beds. Some bounding surfaces appear to control the spalling of case hardened surfaces, although there is no detectable difference between beds above and below such surfaces. Sapping and cove weathering, which are concentrated on the north face, are restricted to certain bounding surfaces. El Morro's entire geologic picture is complex due to the variability in orientation toward prevailing, rain-bearing winds and exposure to the sun (both of which affect surface wetting) and to fluctuations in temperature that are responsible for frost weathering. A characterization of the distribution and movement of moisture throughout the outcrop is crucial for a more complete understanding of weathering at El Morro.

Stephen Aaron Cross, formerly with the NPS is an independent consultant and received his MS in Geology from New Mexico Institute of Mining and Technology.

University of Pennsylvania student Veronica Aplenc at work on El Morro stone. Photo UPenn ACL.

Dawn Melbourne

Epoxies, Grouts, and Inscriptions

Documentation at El Morro indicates that damage has occurred to areas of inscribed sandstone, in the form of detachment and subsequent exfoliation of layers of stone. In 1993 the problem of detachment at Inscription Rock was considered urgent when a portion of an inscribed layer of stone fell off the cliff face. The University of Pennsylvania and NPS undertook a joint program to design and test treatments which would re-adhere the detached layers of stone to sound substrate.

During phase one, conservation materials were chosen and treatments were designed based on the characterization of the stone, mechanisms of deterioration, identified environmental conditions, assessment of past treatments, and current research. These treatments were tested in the laboratory and the most promising methods were selected for further testing in the field. Phase two was implemented to field test at Inscription Rock, the conservation materials and systems of application recommended from the first phase. Aided by non-destructive testing (NDT), *in situ* evaluation of grout application and the assessment of the weathering were made possible.

A standard solution to the problem of detachment is injection grouting. Although lime and hydraulic lime based grouts may provide sufficient support for many materials, they do not always demonstrate adequate strength for materials under substantial mechanical stress such as the inscribed stone at El Morro. Because of their excellent mechanical properties, high strength industrial adhesives such as epoxies and cementitious grouts have long been used. These materials completely fill cracks and act as water sealants. Their success is generally equated with total re-adhesion, 100% contact being optimal. Only recently have the physico-chemical effects of this type of application been reconsidered on non-traditional porous materials such as deteriorating stone (natural outcrops vs building materials). Differences in mechanical properties between grouts and the substrate material can be damaging both to the adhesive joint and the substrate. This damage can be exacerbated when contact area between adhesive and substrate is increased, as in complete coverage of a void or crack, altering the capacity of the grout to perform its adhesive function.

While grouting seemed well-suited for reattaching the layers of detaching stone at El Morro, the question remained as to what type of grout and method of application were appropriate for materials under a wide range of mechanical stresses. Since high strength grouts were necessary to sustain mechanical forces, and large differences exist between mechanical properties of grouts and the substrate, it was thought that minimizing the amount of grout necessary to sustain forces exerted on the adhesive might eliminate some of the problems associated with full cavity injection. An experimental program was designed to compare the properties of epoxide resins and cementitious grouts applied in various manners, and to assess their physical and mechanical properties and methods of application and the effects on the stone.

For initial testing of treatments, commercial sandstone similar to El Morro's Zuni sandstone was used. Commercial stone was deemed necessary to eliminate unknown variables encountered using naturally weathered stone from the site and ensuring that test results would represent the performance of the grouts rather than inconsistencies in the stone. "Sandwich" assemblies of unweathered, commercial sandstone simulated the thickness of stone and detachment measured at Inscription Rock. The detachment joints were sealed, then grouted with epoxies and cementitious grouts in the following types of assemblies:

- Types 1,2 & 3—Unmodified low modulus epoxies applied as continuous films
- Types 4, 5 & 6—Low modulus epoxies applied as discrete "spot welds" modified with 5% fumed silica by weight to impart thixotropic properties ensuring that epoxy would not remain in place after injection
- Types 7 &8—Commercial cementitious grouts applied as continuous films
- Types 9 & 10—Combination of modified epoxy "spot welds" with cementitious grout infilling the remainder of void

After curing, these assemblies were subjected to a series of laboratory experiments. Results of the testing program revealed several important differences between the grouts and the application methods. A comparison of mechanical test results demonstrated that although all the grouts and application methods displayed adequate strength to sustain amounts of load applied in shear, not all systems failed in an acceptable fashion. Failure exhibited in assembly types 1, 2, and 3, which employed continuous films of epoxy, resulted in excessive damage to the stone. Assembly types 4 through 10, which employed either discrete epoxy spot welds, continuous films of cementitious grouts, or a combination of both, displayed failure which caused little or no damage, making those systems more desirable because their failure was primarily within the joint.

All grouting systems underwent cyclical freeze-thaw testing without any damage to the stone or the joint. Significant differences in the rate of water vapor transmission were observed. The epoxies greatly reduced the water vapor transmission of the stone, while the cementitious grouts exhibited a more favorable rate of transmission. As a result, the application of epoxies as a continuous film would not be advisable, as it would form a water vapor barrier. However, applying epoxies as spot welds would be more acceptable as it would limit the area where water vapor transmission is hampered, allowing the escape of liquid and water vapor through the more porous surrounding substrate.

It was recommended to field test epoxies applied as spot welds, cementitious grouts applied as void-filling continuous films, and a combination of epoxy spot welds with a cementitious grout infill. Epoxies applied as continuous void-filling films were rejected. The use of epoxy as spot welds alone had the advantage of introducing a limited amount of material into an already weakened system, reducing the amount of hazardous waste and cost. This approach would also limit the areas of contact between the epoxy and stone, reducing the deterioration from differences in the thermal coefficient of expansion of the two materials. The modulus of elasticity of the epoxy is lower than that of the stone, making epoxy desirable as a joint-forming material because, theoretically, it would withstand the stress of expansion of the stone. The disadvantage of using the spot weld system is that the system is dependent on the successful contact between the epoxy and stone.

Although a system of continuous void-filling cementitious grout had the advantage of sealing the void from water, it could make voids larger through water-based chemical dissolution of the stone, or the internal disruptive processes of cyclical crystallization of ice and salts. Cementitious grouts also had the advantage of being non-toxic, easily handled materials. Unlike the spot welds, cementitious grouts applied as continuous films had a greater area of contact, ensuring a higher percentage of successful adhesion. A disadvantage of using a cementitious grout as a continuous film is that eventually the system may fail, and when failure occurs, the weight of the grout could damage the stone and contribute to dislocation.

A combination of both systems offers the advantages and disadvantages of both systems, namely the concentrated strength of the epoxy and the water sealing properties of the cementitious grout. However, a grouting system comprised of three different materials might introduce higher potential failure due to the mechanical differences between the epoxy, grouts, and stone.

A site at El Morro was chosen to field test the three methods in an area with no inscriptions, but where the conditions of the stone were representative of the conditions found with the majority of the historic inscriptions. Prior to treatment, test areas were photographed and the existing conditions were graphically documented. The areas were investigated using a combination of nondestructive techniques (NDT). The NDT showed that all grouting systems imparted greater physical continuity to the treated sandstone when compared with untreated stone (see Ennis, page 35).

The laboratory and field testing of several grouting systems was instrumental in understanding the nature of grouting materials and the effect that application has on their success. Although all of the tested systems of grouting were easily applied in the laboratory, field applications proved more difficult. Due to the high clay content of the stone, which made it expansive upon wetting, it was difficult to preclean the voids and then inject the grouts. This study demonstrated that the success of a treatment depends on both the compatibility of materials and the system of application. Although the epoxy was found to be unacceptable as a grouting material when applied as a continuous void-filling film, it performed very well when applied as isolated spot welds. While the success of the grouts applied during the field testing is still being evaluated, the method of epoxy application should be considered and tested as an alternative to reattachment with full cavity injection using high strength grouts.

Project Team. Dawn Melbourne and Angelyn Bass (formerly with NPS).

Dawn Melbourne is a Project Manager/Architectural Conservator for Integrated Conservation Resources, Inc. and has an MS in historic preservation from the University of Pennsylvania.

Marie Ennis

Non-destructive Testing at El Morro

Marie Ennis and Dennis Sack conducting non-destructive testing at El Morro, Inscription Rock. Photo by Jake Barrow.

Nondestructive tests were conducted at El Morro during the field application of pilot treatments in 1994 (see Melbourne, page 33) and again in 1995 after one year of cure. The tests were conducted by Dennis Sack of Olsen Engineering using Impact Echo and Spectral-Analysis-of Surface-Waves (SASW). Results were analyzed by Olsen Engineering and a report made to the National Park Service. Three locations were selected for testing of treatments to which the NDT tests were applied.

The selected areas of delaminating sandstone were treated by several methods involving the injection of epoxy and grout. Non-destructive testing was performed at the repair sites prior to repairs for control data, and again approximately 24 hours after treatment. Those tests indicated that there had been a general improvement in the structural stability, or stiffness, of the treated sandstone at all repair locations.

Re-testing was scheduled for one year after the initial repairs to determine if the condition of stabilized areas had changed with time and exposure to the elements. At the location of the epoxy "spot weld" repair, the one-year test results were similar to the 24-hour results. At the two locations where the "spot welds" were augmented by cementitious grouting, the test results indicated that there had actually been an improvement in the stiffness of the treated sandstone areas. This strength increase can be attributed to the curing process whereby the injected grout continued to gain strength after the initial 24-hour set. The overall results indicate that the treated areas, which had improved structural stability after initial treatment, were still of improved soundness after one year of exposure.

The use of non-destructive methods to evaluate conditions at this site is appropriate given the historical importance of El Morro. The two methods used, impact echo and SASW, provided the team with data that indicates that the repair techniques utilized here do improve the stability of delaminating sheets of sandstone.

Assessing the entire site, the immense area of historic carvings at El Morro present a logistical challenge, both for determining existing conditions and for implementing treatment. The use of acoustic methods such as impact Echo and SASW requires "hands on" access to each location and the collection and interpretation of numerous data points. Given the enormous surface areas to be assessed, these techniques would be too labor intensive and time consuming for use as an overall diagnostic tool. The nature of the data collected by these techniques, however, does provide valuable baseline information for comparison of before and after physical conditions at specific repair sites.

A non-destructive technique that could be useful for the selection of future repair sites would be infrared thermography. Research performed at the Getty Conservation Institute under the direction of William Ginell has indicated that voids behind the face of a solid stone surface can be imaged with this method. The theory is that there will be a surface temperature differential between areas of solid stone relative to areas where voids are present beneath the surface. The advantage of this method is that large surface areas of stone can be imaged relatively quickly without "hands on" access. This would allow for the non-labor-intensive collection of data showing those locations where voids occur behind the face of the stone. The information collected this way would not provide quantitative data such as the thickness of a delaminated section of stone, but the qualitative data obtained could be used to pinpoint locations where further investigation and potential repairs might be made.

In summary, using non-destructive techniques, it is possible to evaluate the structural soundness of delaminating sandstone before and after stabilization treatment. The repair techniques developed and implemented at El Morro by the team from UPenn's Historic Preservation program resulted in measurable improvement in the stability of the stone surfaces. After one year of exposure to weather, the repairs were still effective.

Project Team. Marie Ennis, Dennis Sack of Olsen Engineering; Dawn Melbourne and Angelyn Bass, field conservators.

Marie Ennis, Structural Engineer, is Principal for Einhorn Yaffee Prescott Architecture and Engineering.

Anne Oliver

Pilot Conservation at El Morro

For at least 700 years, people have been marking their presence at El Morro with pictographs, petroglyphs, and written inscriptions. But the Zuni sandstone of the outcrop is very friable, and the characteristics which make it so easy to inscribe also render it susceptible to relatively rapid deterioration. To preserve this remarkable record of human passage, a comprehensive documentation and research program was conducted through the combined efforts of El Morro National Monument, the Intermountain Cultural Resource Center of the National Park Service, and the Architectural Conservation Laboratory of the University of Pennsylvania.

As identified in the assessment and geology projects (see Padgett and Barthuli, page 28, and Cross, page 30, in this issue), the major deterioration conditions which affect the inscriptions at El Morro include cracking, detachment, spalling, and granular disintegration.

In an effort to slow the rate of deterioration and loss, a range of conservation methods and materials was identified to address these conditions. To evaluate the effectiveness and practicability of different materials and methods on the Zuni sandstone, three testing programs were designed and conducted at the Architectural Conservation Laboratory of the University of Pennsylvania. These projects researched and tested the use of epoxide and cement-based grouts to fill voids and reattach fragments (see Melbourne, page 33), epoxide and ethyl silicate consolidants to reestablish intergranular cohesion around eroded inscriptions (described below), and mechanical pins to secure detached fragments (described below).

To apply the results of the testing programs, a pilot conservation treatment project was conducted at the El Morro in the summer of 1996. This project allowed for the *in situ* application and evaluation of the pinning and consolidation treatments which had proved viable in research and laboratory testing programs, and for the testing and evaluation of known and effective treatments not yet tested on Zuni sandstone. All treatments were first applied to uninscribed Zuni sandstone near the outcrop. After evaluation, the most effective of these treatments were applied to several inscriptions which exhibited the range of deterioration conditions found at the site, and which were in imminent danger of loss.

Mechanical Pins

In previous tests at El Morro, the use of epoxide and cement-based grouts to secure detached fragments was deemed ineffective because all of the materials were non-reversible and proved problematic in field applications despite good lab results. Moreover, consultation with Native Americans suggested these techniques were culturally inappropriate. To explore a third system of reattachment, research on the use of mechanical pins was conducted by graduate student Scott Kreilick. A dry system, which relied on friction and pressure rather than on adhesives to secure the pin, was chosen to minimize disruption of the sandstone and to maximize reversibility.

A wide range of threaded stainless steel pins and threaded nylon pins and sleeves was

Project Team (l-r): Aaron Cross, Anne Oliver, Julie Barrow, Scott Kreilick, John Lujan. Photo by Frank Matero.

selected for testing at El Morro on an uninscribed boulder. From among these options, the most effective system for use at El Morro proved to be a threaded stainless steel pin inserted in a nylon sheath. Using this system, pins were used to reattach the broken fragments of an inscription which had fallen to the ground, as well as to secure the detached slab immediately surrounding that inscription. Voids behind the surface of the inscription were filled with a cement-based grout (see below); cracks and detached edges were filled with hydraulic lime-based mortar (see below) to redirect water away from these vulnerable areas.

Adhesives

To treat stone which exhibited spalling, two materials were tested for use as adhesives. These were an acrylic resin, Acryloid B72, and an acrylic emulsion, El Rey Superior 200. Both materials are very stable in exterior environments, but both reduce the water vapor permeability of the material to which they are applied. For this reason, their use was confined to areas where an adhesive was necessary to reattach a spall.

To compare the performance of the two materials, different concentrations of Acryloid B72 were brushed onto the test boulder. All concentrations darkened the stone considerably, and their use was rejected. Different concentrations of El Rey Superior 200 were applied to fragments of Zuni sandstone found at the base of the cliff. The 10% solution, which produced no discoloration, was used to reattach several spalls in one inscription.

Consolidants

Consolidants are used to re-establish intergranular cohesion in stone which exhibits granular disintegration; both epoxy resins and ethyl silicates have been used successfully in situations similar to that at El Morro. To test the relative effectiveness of these materials for the consolidation of Zuni sandstone, a testing program was designed and conducted at the Architectural Conservation Laboratory by graduate student Veronica Aplenc. Samples treated with an aliphatic epoxy resin and a commercial ethyl silicate were tested for water absorption, depth of penetration, weatherability, and abrasion resistance. The epoxy system imparted greater resistance to abrasion and caused less change in the water absorption rate of the stone, but both materials proved satisfactory as consolidants.

Both consolidants were applied to an eroded area of an uninscribed boulder at the base of the outcrop. While both were effective, the ethyl silicate proved easier to use in the field because no weighing, measuring, or mixing was required. The ethyl silicate was applied over and immediately adjacent to four badly eroded inscriptions.

Grouts

In 1994, epoxide resin and cement-based grouts were tested in the laboratory and applied in field tests at El Morro (see Melbourne, page 33). Based upon those test results, the cement-based Jahn M40 Injection Grout was used during the pilot conservation treatment to fill voids behind detached inscriptions.

Infills

A known and tested infill material for stone and masonry is a 3:1 mixture, by volume, of sand and hydrated hydraulic lime. To make the fills less obtrusive, however, masonry pigments are often added to the mortar to match the color of the surrounding stone.

Pigmented fills were used to fill cracks and detached edges on one inscription. However, their use was not recommended for most inscriptions because the pigments leave stains wherever any excess mortar touches the stone; these stains are difficult to remove without further eroding the stone. Unpigmented mortar was used for all other infills, to which a water-based wash containing local soil and clay was applied while the mortar was still wet. The wash stained the mortar to a color compatible with the surrounding stone.

Conclusions

All of the treatments applied at El Morro will be evaluated over the course of several years. The final evaluation will provide the Monument staff with recommendations for a range of methods and materials for the conservation of the inscriptions. These treatment recommendations, when used in conjunction with procedures designed to reduce the impact of deterioration mechanisms on the inscriptions (such as the re-direction of ground and surface water away from affected areas of the outcrop and the removal of harmful vegetation), will help to ensure the long-term preservation of the site.

Project Team. Field supervisor, Anne Oliver; Stephen Aaron Cross, park resource management specialist; Ken Adams, El Morro Facility Manager; and Scott Kreilick and Veronica Aplenc, graduate students.

Anne Oliver is an architectural conservator in private practice; she received an MS in Historic Preservation from the University of Pennsylvania in 1994.

Kathleen Fiero

Cliff Dwelling Walls
The Earthen Plaster Project at Mesa Verde

Earthen plaster is an integral part of Pueblo architecture. At Mesa Verde, with its numerous standing structures protected by alcoves, the plaster is very apparent and its importance to the original inhabitants obvious. Wall dados and auras around doorways are very common. More elaborate decoration is found in virtually every medium to large size cliff dwelling (20 rooms or more).

With 80 years of monitoring the condition of the architectural fabric of the cliff dwellings, it is obvious that certain plaster panels are deteriorating at an alarming rate. The Park became concerned about this over 15 years ago. Several techniques for re-adhering delaminating plaster were experimented with at Mug House in 1981; and an inventory of the location and condition of all of the plaster panels in 18 cliff dwellings was implemented in 1985 and 1987. But efforts to create a comprehensive preservation program to address the special problems of this ephemeral fabric faltered for lack of funds and inability to find trained conservators interested in researching the problem. Without a time-tested field program the NPS was not willing to fund such a preservation project, and without funding no one was interested in developing a program to address the problem.

This changed when Frank Matero of the Architectural Conservation Laboratory of the University of Pennsylvania visited the Park. He had been working with the Southwest Regional Office on the conservation of historic plasters at Fort Union and Fort Davis. He and Jake Barrow had implemented a comprehensive program to deal with the lime plaster project and they both felt that a similar approach could be used for earthen plasters. Frank was interested in training his conservation students at UPenn simultaneously as he was developing a comprehensive approach to the documentation and preservation of earthen plasters. Also with the help of both the NPS and private funding, Frank felt we could implement such a program. He visited the Park for the first time in 1993 and on the basis of that exposure to the resource came up with a preliminary program. The project was divided into three phases: 1) preliminary field visit, chemical and physical characterization of the plaster and archival records search of previous work in this area, development of a method and system to document the extent and condition of the plaster; 2) documentation and assessment of all the prehistoric plaster, digitization of this graphic and text data, laboratory testing, and design of an environmental monitoring system; 3) implementation of pilot preservation techniques, first, *in situ* testing of the various techniques and then full implementation, installation of the environmental monitoring system, and collection of environmental data for nine months. Phase 1 took place in 1994 and was funded by the NPS. The field work for Phase 2 took place in 1995 and the digitization and report writing in 1996; and the initial field testing of the preservation techniques and the installation of environmental data in 1996. The collection of environmental data is on-going. In 1995 the project was funded by an architectural conservation grant from the Getty Grant Program of the Getty Foundation (the first such grant awarded to the NPS, and the first such grant to fund work on an archeological resource), a grant from the Ballantine Family Trust, and Mesa Verde National Park. In 1996 the project was funded again by the Ballantine Family Trust, the Colorado State Historical Fund, and a NPS Challenge Cost Share grant. Mug House, an 80-room cliff dwelling on Wetherill Mesa, was selected for the project because of the deteriorating condition of an important group of painted plasters, the early testing of

Students documenting kiva plasters at Mug House. Photo by the author.

Detached and delaminating finishes in Kiva "C" Mug House. Photo by Frank Matero.

plaster preservation techniques at Mug House and, for Mesa Verde, the fairly complete documentation of the deterioration since excavation and exposure in 1960 of the most elaborately decorated kiva at the site.

This project has been very successful. There are now trained conservators in earthen plaster preservation and there is an established system for documenting and treating deteriorating plaster. The down side has been the difficulty of funding such a multi-phase project. This is probably due to two factors. First, plaster is still not considered as critical to preserve as other structural fabric—mortar, stone, wood. And second, projects that need funding for several years to develop techniques and test them demand an exhausting and time consuming determination to find the needed funds. Frank and I would both agree that without the assistance of colleagues and students in applying for the various grants, this project would not have been possible.

In terms of preservation, we learned that it is necessary to identify (document) the resource, understand its treatment and maintenance history, its chemical and physical characteristics, and the environmental parameters to which it is exposed to understand the causes of its deterioration. Only then is it possible to treat the problem and establish a program for long-term preservation. In the case of Mug House the final decisions about the long-term management of the various plaster panels have not yet been made. The interpretive needs of the Park as well as the ability to fund the recurring needs of certain panels for maintenance must be considered. Such options as backfilling, systematic and regular monitoring of the condition of the plaster, and regular treatment of certain panels will be considered.

Kathleen Fiero is an archeologist at Mesa Verde National Park and serves as preservation crew leader.

Frank Matero

Managing Change
Conservation of Surface Finishes at Mesa Verde's Cliff Dwellings

The preservation of architectural ruins in prehistoric and historic sites presents great difficulties for those who develop and implement resource management programs. Current practice in the conservation and interpretation of such sites attempts to maximize documentation and retain the original material *in situ*, and at the same time requires that the interpretation of the ruins be sensitive to their preservation and be intelligible to the public. This is a difficult problem for any structure in a ruined state, and especially for fragile elements such as painted earthen plasters, which are best understood in their original context but are also highly susceptible to deterioration and loss.

Despite earlier practices of complete or selective removal of architectural plasters and finishes from ruins and archeological sites, preservation and interpretation *in situ* are now ideologically the preferred solutions, even if backfilling is the only option. *In situ* conservation of architectural plasters ensures the possibility of future studies of the whole resource, and it affords opportunities to view the ruin as a once-complete structure. Surviving plasters with their finishes, in particular, contribute significantly to our understanding and appreciation of these sites by providing information on aesthetics and technology, and possibly increasing our understanding of the sites' architectural function and status. In addition, surface finishes make tangible and human what otherwise might be incomprehensible to the visitor and scholar alike.

In situ preservation of extant plasters in ruined sites has received limited study, due to earlier attitudes involving their selective removal and the lack of research in site conservation techniques. The little research that has been executed has focused on lime plasters on stone or brick masonry. With the exception of an initial study on the conservation of mud plasters at Mesa Verde 16 years ago (Silver 1981), little scientific research has been conducted on appropriate conservation treatments for earthen plasters. In 1985, 1987, and 1991, a general survey of the surviving plasters was initiated at Mesa Verde in order to quantify the resource and draw attention to its condition.

Program Design

Phase 1. With funding from Mesa Verde National Park, Phase 1 was begun to collect documentation on the study of prehistoric plasters in the American Southwest, and, in particular, at Mesa Verde; on plaster conservation in general; and on the archeological and management history of Mug House (a history found in early excavation records and stabilization reports). The collected information proved to be critical in establishing the extent and previous condition of the masonry and plasters from the time of excavation and stabilization to the present. Also, during the summer of 1994, a detailed field study of the plasters' specific conditions was made on site in order to develop standardized nomenclature and objective recording techniques. In addition, several highly unstable areas of plaster were temporarily secured as emergency conditions arose.

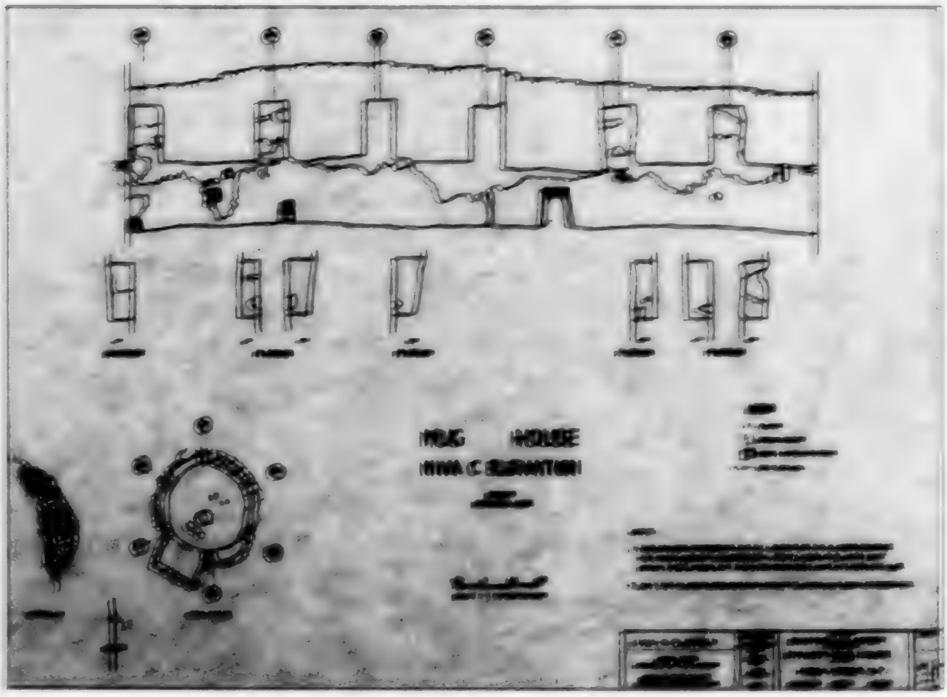
A second major component of Phase 1 included the analysis and characterization of the plasters utilizing the samples taken from selected sites within Mug House. Information assembled included micromorphology, execution techniques, composition, and overall physical and chemical properties. Complete examination of these samples included a mineralogical and microscopical analysis of the plasters using optical microscopy, scanning electron microscopy, analytical electron microscopy (EDS), and X-ray diffractometry (XRD).

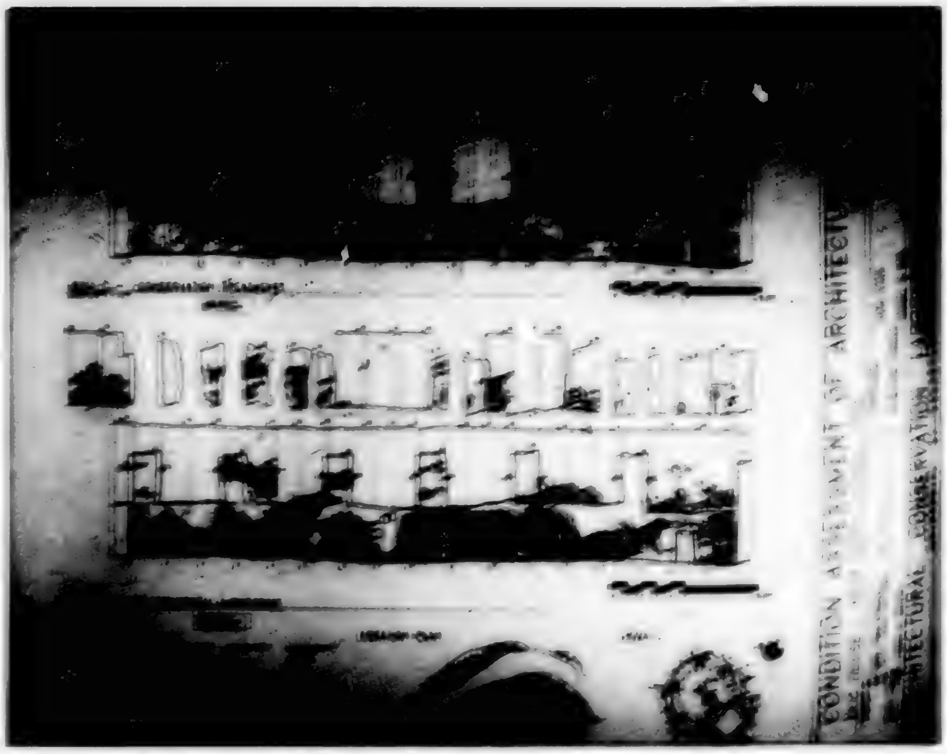
Techniques of injection grouting for reattachment using hydraulic lime were tested based on previous related laboratory and field tests. Two principal deterioration mechanisms—substrate detachment, and intralayer delamination (identified during the field study)—were addressed in a preliminary laboratory treatment program on facsimiles. This was done in order to evaluate appropriate treatment options for further testing both on and off site during Phases 2 and 3.

Phase 2. Phase 2 was primarily concerned with the detailed conditions survey of the Mug House plasters and the environmental monitoring of Kiva C. Building on the earlier parkwide plaster survey, a detailed recording of the architectural context and conditions of the plain and decorated wall plasters at Mug House, was completed using the survey methodology developed in Phase 1. This provided accurate and detailed base-line documentation for immediate and long-range monitoring of the plasters and will serve as a guide for future conservation treatments.

A second major component of Phase 2 was the design of a small-scale environmental monitoring system for Kiva C by John Fidler and Barry Knight of English Heritage. This will allow a better understanding of the site conditions identified as essential in diagnosing the past and current deterioration of the plasters. Conditions include ambient temperature and relative humidity within the site's alcove, and above and below grade, surface temperature, ground/wall moisture and salts, and wind-speed. Microchip data-loggers will reduce the need for frequent data retrieval on site.

Preliminary documentation of Kiva "C," Mug House.





Condition assessment of architectural surface finishes, Kiva C, Mug House. UPenn, 1996.

As part of the monitoring program, facsimile samples treated during Phase 1 were left on site for natural weathering, and will be assessed after one year of exposure. A final report on the environmental monitoring results will be produced in fall 1997 as part of Phase 3.

Phase 3. Phase 3 was primarily concerned with the design and implementation of the research and experiences of the previous phases brought together in a model treatment program on site, and with the installation of the environmental monitoring system designed during Phase 2. During Phase 3, basic stabilization as determined by Phases 1 and 2 was performed and evaluated in the documentation, display, and implied maintenance of the plasters and masonry architecture at Kiva C. Photographic, graphic, and written documentation of the conditions before and after treatment were carefully recorded, as were all treatment techniques executed. Treatment results will be monitored over the research period, and instructions for continued monitoring by the National Park Service will be provided as well. A summer field program was instituted to provide field training for graduate students in conservation and National Park Service staff.

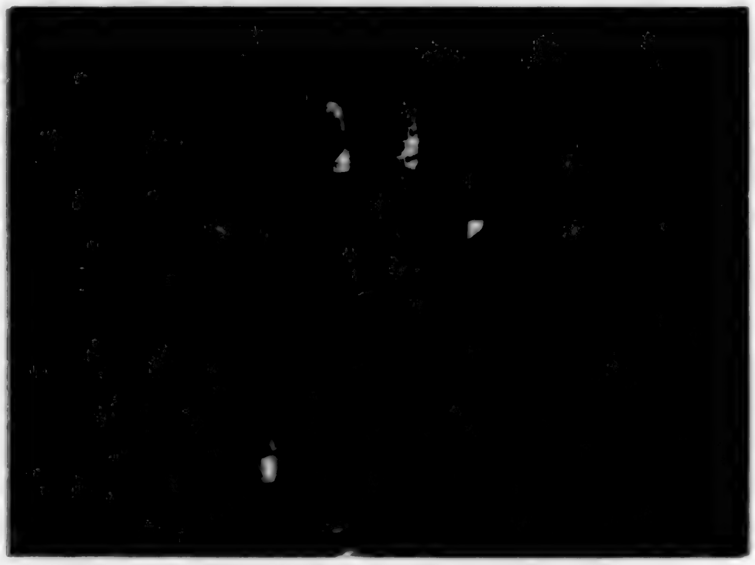
Methodology

Architectural Survey: In preparation for the graphic recording of previous and existing conditions, a sector-by-sector architectural survey of each room/space containing surviving plasters and surface finishes was undertaken at Mug House. Information recorded included masonry construction materials and techniques, architectural features, and previous stabilization efforts for each room/space. Architectural terminology was based on archeologists' accepted regional vocabularies for Mesa Verdean and Puebloan architecture in general.

A complementary survey of architectural information was considered a necessary preface to conditions recording for several reasons: First, by describing the architectural materials, features, and repair campaigns for each sector, surveyors educated themselves with the type, variation, and extent of the architectural fabric before recording the range of symptomatic conditions. Second, by observing and recording the variables of location, exposure, materials, construction, and previous repair with respect to condition, critical connections could be made between the cause, effect, and recurrent patterning of deterioration. Such associations ultimately define the type and rate of deterioration and help establish the necessary conservation interventions. Although not part of this project's goals, the basic documentation of the architectural context of the surface finishes could assist archeologists in a better understanding of the application, use, and meaning of these materials.

Conditions Survey: The photographic documentation of surface finishes at the Mesa Verde site of Mug House was begun in the 1995 field season. Conditions were recorded on specially prepared architectural survey forms, and graphically documented on 35mm rectified photographs. All condition field notes were transcribed to a graphic-

Environmental monitoring at Kiva C being installed. Kathleen Fiero, John Fidler, and Kecia Fong. Photo by the author.



Graduate student Kecia Fong applying treatments at Kiva C. Photo by the author.

symbol format using color acetate overlays on 8"x10" black-and-white prints. Past conditions were recorded and verified according to the archival documents.

Computer Recordation: The translation of the recorded field conditions and past and current interventions into digitized data and computerized drawings was the last phase of the documentation process. Several software programs, including Adobe Photoshop, Spitfire-Image, AutoCAD, and Access, were used to process and analyze data and manipulate and retrieve data combining graphic, textual, and numeric data. The piecing together of the individual images provided a comprehensive visual representation of the surfaces and spaces, allowing complex analysis of deterioration mechanisms and the rate of change. Among the many things these applications made possible were conditions quantification, such as the percentages of loss over specific periods of time, and the simultaneous display of multiple layers of conditions. Type and extent of deterioration were recorded with a descriptive glossary of terms with designated graphic symbols organized according to the additive and subtractive result of the decay mechanisms. It is hoped that this prescribed system will become the establish standard nomenclature for the objective recording of surface finishes.

Frank Matero rehydrating and reattaching earthen surfaces at Long House. Photo by Jake Barrow.

Conditions Assessment: Short of long-term continual monitoring, periodic assessment of conditions by means of an objective, descriptive symptomatic survey that records both type and extent of deterioration affords the most practical and accessible documentation needed to understand a structure's or material's rate and pattern of decay or change. This information is critical in both quantifying and explaining the mechanisms of deterioration before any interventions are tested or strategies planned.

Although definitive statements regarding the etiology of the various types and extent of deterioration observed at Mug House, and specifically for Kiva C, must be deferred until the eight-month period of environmental monitoring has been completed, three general correlative observations can be made on the basis of the survey:
(1) Room/space location (exposure and grade) is a significant factor in determining the overall condition of the architectural finishes. This is predominantly due to the effects of water (rain, snow, or ground water) on the earthen materials.
(2) Room/construction and use-history appear to play a role in affecting the early condition history of the finishes. Partial vitrification from burning, the unstable application of numerous plaster layers, and the presence of carbon soot deposits between layers have affected the durability and hence the condition of the finishes both before and after burial and excavation. (3) Excavation and subsequent exposure to the elements—even in a protected environment such as the cliff-dwellings of the Mesa Verde—have caused the most damage to the fragile surface finishes.

The 1996–97 treatments at Mug House will be re-evaluated after one year of exposure. Together with the environmental data, a conservation plan for the site will be proposed, including preventive measures for site protection.

Project Team. Field supervisors, Kecia Fong and Anne Oliver; Maria Isabel Beas, computer documentation; Kathryn Dowdy, photodocumentation; John Fidler and Barry Knight, environmental monitoring; Mary Griffiths, geology. Treatment: Kecia Fong, Renee Jones, and Caroline Finch. Jeanne Marie Teutonico generously provided much assistance to this project.

Frank Matero is Associate Professor of Architecture and Chairman of the Graduate Program in Historic Preservation at the University of Pennsylvania. He is guest co-editor of this issue of CRM.

Linnaea A. Dix

Materials in the Laboratory
Earthen Plasters, Mortars, and Paints From Mug House

The National Park Service is charged with the preservation and maintenance of the Pre-Columbian legacy at Mesa Verde National Park, located in the southwest corner of Colorado. This responsibility extends beyond the structural stability of the ruins to include preservation of the more ephemeral plasters and paints which are rapidly deteriorating and being lost. In 1994, the Park Service, in cooperation with the University of Pennsylvania, embarked on a phased pilot project to develop a system for documenting and stabilizing prehistoric earthen plasters at Mesa Verde. Mug House was selected as the model site because it has been fully excavated and documented, and because it contains some of the most significant and intact Pre-Columbian plasters in the Park. A critical phase in the project was the characterization and analysis of representative plaster, paint, and mortar samples to gain a basic understanding of the earthen building materials used at Mug House. Kiva C, the most elaborately decorated kiva in Mug House, was the primary focus of the investigation. Samples from Room 28, an adjacent room, were characterized for comparative purposes.

Mug House

Mug House is a Classic Pueblo period (A.D. 1100-1300) cliff dwelling located on Wetherill Mesa, the western boundary of the Park. It occupies a west-facing alcove and is comprised of 80 rooms, two round towers, eight kivas, and eight courtyards. The above-ground, rectilinear, unit-style pueblos conform to the shape of the alcove and are constructed of sandstone blocks laid up in earthen mortar. Earthen plaster covers the interior walls of the kivas and above ground rooms, and some of the exterior walls.

General Methodology

Archival research provided insight into deterioration rates and past stabilization work at Mug House. On site, an extensive conditions survey and an *in situ* visual inspection of the plasters led to the establishment of the sequence of finishes. During the site visit, 20 representative samples of plaster, paint, mortar, and soil, primarily from Kiva C, were collected for further investigation.

In the laboratory, characterization of the samples was based on light microscopy and geophysical tests. Basic physical characteristics of each of the 20 samples were recorded using mounted cross sections examined with reflected light microscopy. Based on the results of this survey, eight samples were selected for further study of micromorphological features using thin section examination in polarized light, bright, and dark field microscopy. Due to the limited quantity of sample material and the difficulty of separating plaster layers, geo-physical tests were limited to base-coat plaster from Kiva C and mortar from Room 28. The tests included grain size distribution, plastic limit, liquid limit, soluble salt content, pH, and color. Additional chemical information was gained through x-ray diffraction analysis and

Mug House, Mesa Verde National Park.

scanning electron microscopy with elemental dispersive x-ray analysis.

Paint finishes from both Kiva C and Room 28 were also characterized. Physical characteristics were examined using cross and thin sections, and color matched to a standard color system. Pigment composition was evaluated through the use of micro-chemical spot tests and confirmed with scanning electron microscopy with elemental dispersive x-ray analysis. Results of the laboratory analysis are summarized in the following table.

SUMMARY OF DATA RESULTS

	KIVA C	ROOM 28
Number of Layers	8-14	2
Particle Size Distribution	Clay Loam/Sandy Clay Loam 30% Clay 21% Silt 49% Fine Sand	Clay Loam 29% Clay 31% Silt 36% Fine Sand 4% Coarse Sand
Plastic Limit	17.1%	17.3%
Liquid Limit	21%	26%
Plasticity Index	4	9
Soluble Salts	Sulfates, Carbonates	Nitrates
pH	6.2	6.6
Munsell Color (base coat)	7.5 YR 6/6 Reddish Yellow	7.5 YR 6/6 Reddish Yellow
Clay Minerals	Kaolinite with some Illite and Smectite	Kaolinite with some Illite and Smectite
Non-Clay Minerals	Quartz Gypsum	Quartz
Elemental Profile	Si, Al, O - primary Fe, C, Ca, K, Mg, S	Si, Al, O - primary Fe, C, Ca, K, Mg

Conclusions

Change in Appearance

The wall surfaces of Kiva C and the exterior of Room 28 were treated in different ways by the inhabitants who occupied Mug House. The interior of Kiva C was plastered at least five times and elaborately painted in the later periods of its occupation. In contrast, the west exterior wall of Room 28 received only one coat of plaster and one painted finish. No finishes remain on its interior. The practice of frequently replastering kiva walls is common throughout the prehistoric southwest. Variations in treatment almost certainly reflect the uses of and attitudes toward the spaces by their inhabitants.

Plasters

Ancient puebloan plasterers used different, although similar, recipes in Kiva C and Room 28. The plasters in both rooms are similar in terms of the basic features of the fine and coarse fractions of the samples, color, pH, clay mineralogy, and elemental composition. The gross principal differences between the Kiva C plasters and the Room 28 plasters are the number of layers applied to the wall (14 layers of paint and plaster in Kiva C vs. 2 layers in Room 28), layer thickness (the Room 28 layers are much thicker than those in Kiva C), and the particle size distribution (plaster from Room 28 contains a higher ratio of coarse to fine particles than the Kiva C plasters). This evidence suggests that disparate, though similar, soils were used to prepare the earthen plasters for the two rooms, or the same soil was enhanced through sifting or the addition of sand to better suit its intended use.

Compositional analysis provides insights into some of the critical properties that make plaster durable and suggests that the Pre-Columbian cultures had an empirical knowledge of the materials required for durable plasters. The base coat plaster is a sandy clay loam (39% clay, 4% silt, 49% fine sand), a recipe that approximates the National Bureau of Standards recommendations for a stable adobe mix. The fine sand controlled shrinkage, an important performance property for a surface finish that is aesthetic as well as insulative. The plaster's liquid limit, plastic limit, and low plasticity index also suggest that the plaster is fairly resistant to swelling and shrinkage in the presence of water. The mineral composition of the clay fraction supports its stability as well; the dominant clay mineral is kaolinite, a stable clay mineral, with only small amounts of the more reactive clay minerals illite and smectite. Gypsum in the plaster may have enhanced its setting properties and continues to enhance its durability.

Mortars

Mortars and plasters were clearly distinguished in the laboratory. Similar in many respects, contrasts between plasters and mortars relate largely to particle size distribution and its effect on texture and soil behavior, and in the non-clay minerals in the soil. Mortars appear coarser in texture than the plasters and contain anomalies and inclusions not observed in the plasters. Physical tests showed that the mortars and plasters contain approximately the same percentage of clay (roughly 30%) but deviate in their ratios of silt and sand. The Kiva C plaster contains a greater percentage of sand (49% fine sand) than the mortar (40% sand: 36% fine sand, 4% coarse sand), a feature that minimizes shrinkage. The mortar has a higher plasticity index than the plas-

Kiva C painted plaster dado.

Cross-section of Kiva C layers, Mug House.

ter. indicating that the mortar is less dimensionally stable in the presence of water. X-ray diffraction analysis revealed the presence of gypsum, a non-clay mineral commonly found in southwestern soils, in the Kiva C plaster, but not in the mortar sample. The variations found were what one might expect, given the structural function of the mortar (knitting together the sandstone wall) versus the decorative and insulative function of the plaster. Other factors that could influence material selection are the importance of shrinkage resistance in the plaster (not quite as important in the mortar), and preparation at different times or by different people.

Painted Finishes

Basic painting techniques in Kiva C and Room 28 were quite similar. *In situ* observation of the walls in both rooms and microscopic examination of cross and thin sections suggest that the general practice was to cover the sandstone wall with a tan base plaster by hand, paint it with diluted clay washes, incise the decorative design into the plaster with a pointed instrument, and apply any additional paint with brushes. Striations in the plaster and the difficulty of clearly distinguishing the horizon between plaster and paint in many of the samples lead to the conclusion that the incised designs and fresh paint were applied to the wall while the plaster was still damp.

The painted finishes are essentially washes of diluted clay, probably derived from mineral nodes, rocks, and clays of the desired color. Under the microscope, the finishes have a smooth, clayey texture with few inclusions and intense color. Clay and microcrystalline calcite are the likely binders. The presence of organic binding media in the finishes remains unknown.

Microchemical tests showed that paint pigments are derived from mineral sources and were the same pigments employed by Pre-Columbian muralists in other southwestern settlements. The red finish in both rooms is iron oxide. The orange finish is very similar to the red finish except for the orange color of its clayey matrix; it too is iron oxide. The white layers are all calcium carbonate. White layers are typically thicker than the red and orange layers, possibly to increase their opacity and hiding power.

Linnaea Dix is Assistant Conservator for Wharton and Griswold and Associates in Los Angeles and received her MS in Historic Preservation from the University of Pennsylvania in 1996.

Photos by the author.

Jim Trott

Ruins Preservation

Pre-Colombian and Historic Ruins Preservation in the Arid Southwest

From the time human beings first occupied the North American continent, they have sought shelter. Throughout history shelter has developed in many different forms, including the construction of stone masonry and earthen structures. Many of the earliest buildings and associated remains have become national parks and monuments in the Southwest. Consequently, the National Park Service has become responsible for their preservation, and, during the past 90-plus years, has provided varying levels of maintenance.

During the late 1890s and early 1900s American archeological research concentrated on large archeological sites related to the modern tribes of an area, and moved forward in perspective rather than backward in time. American archeologists such as Adolf Bandelier, George Pepper, Frank Cushing, and Jesse W. Fewkes began to discover the American Southwest. They encountered the major cultures of the Southwest at a time when some of the young people of those cultures had never seen a white person. In 1907, Fewkes, then head of the Bureau of American Ethnology, pushed for an expanding archeological knowledge base by re-examining old excavations and conducting new excavations. He stipulated that the sites should be prepared for public visitation "by applying simple stabilization procedures." This emphasis on excavation of archeological sites for the public developed into a progressive excavation of new sites. However, this period of excavation was short, because the costs of stabilizing structures rapidly ate up the meager funds appropriated annually for "antiquities." The lack of adequate funding for preservation persists to the present.

During the early 1900s, stabilization techniques primarily consisted of the use of cement capping and native soils. Other techniques were also tried, such as the encapsulation of walls and construction of a shelter (Casa Grande National Monument); and anchoring and aligning of walls through the use of steel angles, rods, and turnbuckles (Mesa Verde National Park).

As the 20th century unfolded, archeological activity in the United States became popular. Eastern institutions of higher learning sent archeologists into the Southwest to expand their knowledge of its history. Cultures were identified, time periods delineated, ethnography introduced, professional meetings convened, and development of archeological sites for research and public use generally established—all these activities influenced the National Park Service. Noted archeologists such as Earl Morris, Alfred Kidder, and Neil Judd excavated, documented, treated—and at times reconstructed—portions of the sites they worked on using stabilization techniques as before. These activities constitute the fundamental origins of ruins preservation in the Southwest. For better or worse, everyone following these individuals must reflect on the work of these forerunners.

In 1924, ruins preservation became a recognized and regularly funded activity in the NPS. Then the Great Depression brought a significant change to archeology in the Southwest. Relief

Chaco preservation crew in 1991. Photo by Mike Taylor.

Capping Fort Union hospital walls in 1959. Photo by R. L. Wilson, NPS.

work spilled into archeology and stabilization, and emphasized the employment of both unskilled workers and skilled workers—the latter including engineers, artists, and anthropologists. More archeological sites were excavated and stabilized. This decade was critical to the development of modern archeology.

A change in the approach to ruins stabilization can be detected between 1930 and 1935, probably due to a recognition that the authenticity of original architecture was being compromised. On March 31, 1931, the National Park Service issued the following notice:

> The National Park Service is seeking means of protecting Pueblo ruins from weathering. The ideal solution would be a transparent, waterproof coating which could be sprayed on the walls, but no suitable product has been found, and the Service announced today it would welcome suggestions for a substitute.

This call reflected a desire to find less invasive materials and methods to stabilize walls. It was hoped that a single cure-all material existed that could be applied to protect the surface of ruins and replace the heavy-handed work of reconstituting walls. This desire for a material solution remains a proverbial carrot in front of preservationists today.

Surely marketing people must have seen the potential for such a miracle cure, and it was probably this promise that led to the field testing of a variety of proprietary materials. Many of the national parks had their own materials that they tested on their ruins. But none emerged as the solution. Frustrated, the National Park Service working collaboratively with Stanford University decided to make its own preservative, NPSX. It also failed.

The search for wonder cures did not end with NPSX. In 1932, Standard Oil presented their contender which they touted as the cure for earthen mortar erosion, Soil-Bitumen 1, an admixture of emulsified asphalt. In 1940, the Director's Committee on Ruins Stabilization declared that bitumen-stabilized soil demonstrated a positive value, stating, "It is highly probable that they (bitumen-stabilized soil and techniques) will continue to occupy an important position in the family of techniques that may eventually be developed." Unfortunately, the claims for bitumen-stabilized soils did not prove out.

Asphalt mixtures continued to be used in different forms up into the late 1940s. The only one of these developments that succeeded was contemporary stabilized adobes which are treated with an asphalt emulsion. Asphalt-stabilized adobe bricks became a commercial industry standard.

The 1940 Director's Committee on Ruins Stabilization discussed problems in ruins preservation. They recognized that "The basic deficiency is material," and that "It is very probable that superior methods of application will quickly follow the development of suitable materials." However, in the interim period, cement mortar colored to match the native mortar was used, although its position as a major mortar solution had slipped.

Between 1941 and 1946, soil cements (combinations of soil and Portland cement) were being studied, and were deemed a satisfactory mortar. They were subsequently used in ruins preservation throughout the Southwest. Soil cements tinted with colorants, however, often resulted in unsatisfactory colors or shifts in color over time.

World War II and the Korean War interrupted the search of chemical solutions for ruins preservation. In the 1940s, the value of resins, plastics, and silicon esters was recognized, but they were not researched until after World War II. The 1940 Director's Committee on Ruins Stabilization had the vision to realize that techniques and materials were deficient, and "must be supplemented by materials of different characteristics which probably will be found only in the developments of industrial chemistry. The resins, and silicon ester in particular, appear to offer hope of eventual solution."

Wartime industries also contributed technological developments such as silicone sprays. Between 1958–1968, bonding agents that could permanently adhere to old surfaces were investigated. Out of these studies emerged the concrete adhesive Daraweld®, still used in ruins preservation today. In the late 1960s, a call came from the parks for research to discover a more appropriate mortar. Superintendents as well as other regional personnel requested a controlled program of material research and testing. New mortar amendments and also non-traditional preservation methods such as backfilling were sought.

Casa Grande National Monument test walls from the 1970s, as seen in 1996. Photo by Jake Barrow.

In the early 1970s the desire for a permanent hard mortar was replaced by a thrust to develop a mortar which did not harm the resource as some cements and soil cements did. Testing on original fabric was banned, and in December of 1974 a moratorium was placed on the use of cement in ruins stabilization. New materials had to be evaluated by the National Bureau of Standards. Problems such as cracking or moving walls were monitored to determine if problems existed prior to treatment. Instead of the wall and ruins treatment that characterized past approaches, ruins received the minimum interventive treatment.

In 1973, Dr. Darrel Butterbaugh, a retired chemist from Rohm and Haas Corporation working for the Museum of Applied Science Center for Archeology, University Museum, University of Pennsylvania, Philadelphia, initiated a testing program at Bent's Old Fort National Historic Site and Chaco Culture National Monument (now Chaco Culture National Historical Park). Butterbaugh introduced numerous new chemicals including the acrylic emulsion Rhoplex®, a cement amendment developed for the construction industry. At Chaco, Butterbaugh tested materials on pithouse sites, Lizard House, and Pueblo del Arroyo. Once again, sprays and water repellents were tested. In particular, a Japanese spray solution—Takenaka Aqua-Reactive Chemical Soil Stabilization System—held promise, but failed.

The increasing sensitivity in testing new preservation materials on historic fabric, the limited space in existing ruins, and the variability of exposure motivated more controlled testing. A new testing program was proposed directed by Dennis Fenn, the National Park Service's Cooperative Park Scientist at the University of Arizona. In 1977, a test ruin appropriately named "Kin Fenn" (Navajo for Fenn's house) was completed at Chaco. The test involved the accelerated weathering of mortars in a sandstone masonry ruin, and mortar patties left in open exposure. Despite exposure to all cardinal directions, Kin Fenn and many of the mortar patties still remain today.

Based on these studies, the acrylic emulsion Rhoplex® E-330, along with Daraweld®, were selected as useful. These water-based emulsions were able to strengthen mortar and still allow transmission of water vapor through of the mortar. Rhoplex® E-330 was initially used in the stabiliza-

Fort Union test walls from 1959 as seen in 1996. Photo by Jake Barrow.

tion of Wijiji Ruin at Chaco. Once the National Park Service gave its approval for the use of Rhoplex® at Wijiji, the application of this chemical in ruins stabilization spread rapidly because there was a strong interest in a product to help managers care for their cultural resources. Unfortunately, Rhoplex® was used with little or no understanding of its limitations. Field practitioners didn't know that it could spoil, that it would not set up well in cold temperatures, and that it would not set up in a wet soil that did not dry out. Finally, in the late 1980s, a representative from Rohm and Haas, the company that manufactures Rhoplex®, was invited to a National Park Service ruins preservation training course which helped formalize the correct use of Rhoplex®.

After 17 years of use, Rhoplex®-amended mortars exhibited good and bad results. For the most part, the effects of Rhoplex® E-330 have been beneficial. The long history of use of Rhoplex® E-330 provided a good test case for evaluation and was investigated at three parks—Mesa Verde National Park, Aztec Ruins National Monument, and Chaco Culture National Historical Park—by Bob Hartzler, then a UPenn graduate student in Historic Preservation. His findings clarified the behavior of the material so that users could more clearly understand field attributes (see Hartzler, page 50).

Attempting to slow down the effects of nature on ruins deterioration provides a challenge requiring knowledge of the past and the utilization of diverse methods and materials. There can be no single solution to all of our preservation problems. In the visionary words of the 1940s Director's Committee on Ruins Preservation,

> Stabilization may be said to be standing, gaunt and lean, among a multiplicity of unapplied techniques. The urgent need is exploratory study to determine applicable materials and their use in the light of modern conceptions of material physics and mechanics. Only in this way can progress be carried forward to that goal of preservation required by the organic legislation establishing the Service.

Jim Trott is a Project Manager/Archeologist for the Conservation Program, Intermountain Cultural Resource Center.

Ann Oliver and Sharon Fleming conserve wall plasters at Mission San Jose HS203-B, (north wall fragments 11A and 11B).

Bob Hartzler

Acrylic-modified Earthen Mortar

In the Four Corners region of the United States—where Arizona, Colorado, New Mexico, and Utah join—many ruins of Pre-Columbian cultures remain, including pueblos and related structures made of sandstone masonry and earthen mortar. These ruins often stand fully exposed to the weather; without roofs, without the earthen plasters that may have covered many walls, and often without adjacent supporting walls, which long ago collapsed.

In an effort to stabilize and repair the ruins in its care, the National Park Service for nearly a century has used supplementary materials to amend, or replace, the vulnerable earthen mortar—materials including Portland cement, asphalt emulsion, and more recently, polymer emulsions. At best, these materials provide weather resistance to the mortars without harmful side effects; at worst, they are physically incompatible with the historic stone masonry, causing irreparable damage.

It takes two ingredients to make earthen mortar: soil and water. It requires only water to destroy it. At sheltered sites, some earthen mortar has remained in good condition hundreds of years after its installation. But because most of the ruins are unsheltered, their modern custodians face a relentless opponent. Water attacks earthen mortars during rainstorms, and snow on wall tops and at wall bases melts, causing erosion and soaking into mortar and earthen fill.

Since the mid-1970s, the Park Service has used an acrylic emulsion concrete additive made for the construction industry—Rhoplex® E-330 Cement Mortar Modifier—to modify mortars at some ruins sites. Park Service stabilization experts developed much field experience working with acrylic-modified soil over the years, but sometimes the acrylic-amended mortars did not perform as expected—they deteriorated prematurely—for reasons that were not entirely clear.

A research project begun in 1994, sponsored jointly the National Park Service and the University of Pennsylvania, focused on the performance of this particular soil amendment by establishing a laboratory program of investigation into the interaction between the emulsion and different soil types, and the effects of simulated weather on the amended mortar.

This research was built on earlier field and laboratory research by Dennis Fenn, formerly of the National Park Service, and Darrel Butterbaugh, formerly a scientist with the University Museum of the University of Pennsylvania. Both Butterbaugh and Fenn began experimenting with polymer-based mortar additives more than 20 years ago. As a result of their research, the use of E-330 and similar polymer emulsions has grown significantly within the National Park Service and other natural and cultural resource agencies over the last 20 years.

The National Park Service selected three sites to participate in this research: Mesa Verde National Park, in Colorado; and Aztec Ruins National Monument and Chaco Culture National Historical Park, both in New Mexico. All three are prehistoric pueblo sites constructed primarily of sandstone masonry and earthen mortar, where Rhoplex® E-330 has been used since the late 1970s or the early 1980s.

Soils

Because all three research sites are national preserves, preservation crews there are restricted from excavating soils for mortar repairs within park and monument boundaries. This is considered mining, an activity not normally permitted. Soils must be obtained from alternate sources, usually outside the preserve boundaries, and these soils may or may not match the original soils used by the builders, in terms of mineralogy; proportions of sand, silt, and clay; or color. The task of finding compatible mortars is made more complicated when soils must be blended to achieve suitable color or texture.

Rhoplex® E-330

Rhoplex® E-330 is specifically designed for modifying Portland cement-based materials, and its uses include patching and resurfacing, floor underlayments, pre-cast architectural building panels, stucco, terrazzo flooring, industrial cement floors, and highway and bridge deck repair. The manufacturer, Rohm and Haas, Philadelphia, makes no claims about the performance of the emulsion when used as an amendment to earthen materials.

Acrylic emulsions are often used as adhesives. (Ordinary white wood and paper glues are primarily polymer emulsions, and modern interior paints often use acrylic emulsions as a base.) As the water in the emulsion evaporates, the polymers coalesce into a tough film. No chemical reaction takes place; no curing is necessary. The dried polymer film is insoluble in water. It is presumed that the material works as a soil amendment by acting as an adhesive between soil particles.

Rhoplex® E-330 has several qualities that make it an attractive candidate for use as an earthen mortar amendment. In bulk, it is stable at temperatures between the freezing and boiling points of water. It is water-based, so the issues of volatile solvent evaporation are avoided, and it is compatible with traditional water-based mortars. It is non-flammable and non-toxic. Like other acrylics, and unlike some other polymers, it is relatively unaffected by ultraviolet light. Dry, it is colorless and has little effect on the appearance of earthen mortar.

Research

Three techniques were used to gain information about the use and performance of amended mortars at the test sites: a search of available literature, including the work by Fenn and Butterbaugh; interviews with the stabilization crews at the selected sites to learn about success and failure in the field, and about current practices; and laboratory soil analysis and performance testing of manufactured acrylic-modified mortar samples.

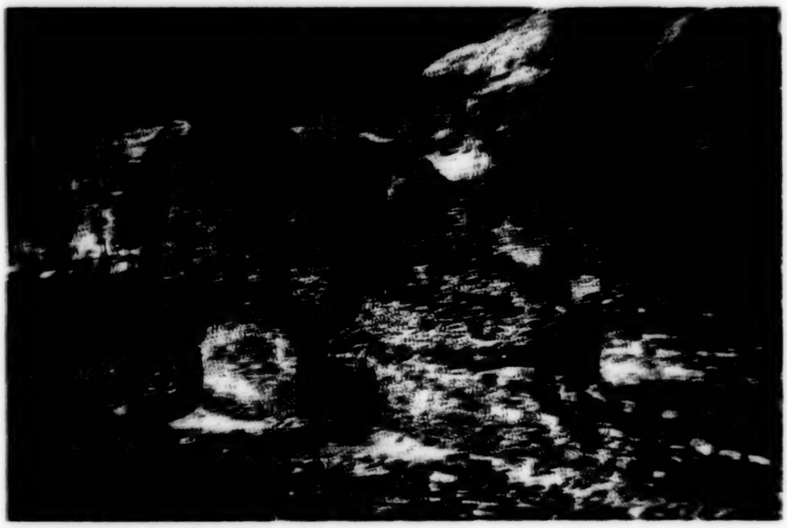
Mortar soils from Mesa Verde, Chaco, and Aztec were collected and shipped to the Architectural Conservation Laboratory at the University of Pennsylvania in Philadelphia for characterization and testing. The soils were individually characterized according to 11 criteria, including: proportion of sand, silt, and clay; type of clay present; amount of shrinkage upon drying; percentage of calcium carbonate; and color.

To test the performance of acrylic-modified mortars, the mortar soils were mixed with water and varying proportions of Rhoplex® to form cylinders and prisms which were subjected to physical tests selected to represent the environmental factors observed on site. These tests included: wetting and drying; freezing and thawing; strength in bending; ability to transmit water vapor; and color.

There are no established standards for testing earthen mortars, so whenever possible, modified American Society for Testing and Materials testing standards were employed. Color was characterized using the Munsell soil color system.

Two tests, wetting/drying and freezing/thawing, were chosen to simulate the predominate weathering features of the sites, water and temperature. They were meant to test the ability of the polymer bonds in the soil to contain the stresses that occur within the mortar when the clays in the soil become wet and expand, or the stresses that occur when saturated soil freezes and expands.

The water vapor transmission test was designed to determine the effect of varying quantities of Rhoplex® on the ability of earthen mortars to transmit water vapor. (Mortar should remain permeable so that water and water vapor can exit wet mortar, allowing the masonry and mortar to dry.)

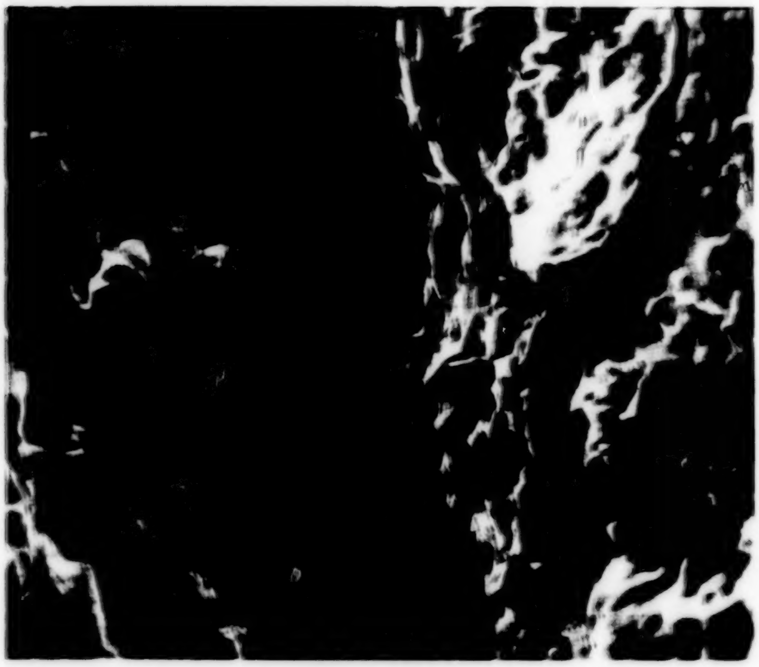


Stone walls of Chaco Canyon laid in earthen mortar. Photo by Jake Barrow.

Results

The addition of Rhoplex® E-330 had some predictable effects on all the mortars tested: as measured by resistance to bending, an increase in the proportion of E-330 to water in the mortar mix always resulted in an increase in strength, regardless of soil type; as measured by the transmission of water vapor, an increase in the amount of E-330 in the earthen mortar always decreased the permeability of the mortar; and when compared to unmodified soil, the addition of E-330 resulted in increased resistance to erosion by water.

Examination of the mortar soils with a scanning electron microscope revealed some interesting differences: Unweathered mortars made from modern repair soils examined at 5,000x magnification revealed a fine network of polymer filaments bridging shrinkage cracks in the soil, and evidence of a polymer coating on some soil particles. Weathered, amended, mortars containing relatively high clay soils revealed torn, feathery fragments, possible evidence of a ruptured polymer



Rhoplex® strands in soil-mortar sample at 5,000X. Photo by Bob Hartzler.

coating, ruptured as the clays in the soil expanded and contracted.

Conclusions

Testing revealed that the most important predictors of success of acrylic-modified earthen mortars are the weather conditions at the ruin and the properties of the mortar soil. Where mortars are rarely wet, the soil type is not as critical as in ruins fully exposed to rain and snow. Where water is a factor, sandy soils with little natural binder are held together successfully with the addition of an acrylic emulsion. Soils with a significant percentage of active clays continue to shrink and swell as they wet and dry, rupturing the polymer bonds. Careful selection of mortar soil can significantly improve the durability of acrylic-modified earthen mortar. But because of special requirements for color or texture, or because of limited soil availability, acrylic-modified mortars may not be an acceptable choice at some sites.

The National Park Service continues to look for materials and techniques that improve the durability of earthen architecture, without compromising historic material. There is not a single answer to solving the problems of earthen mortar deterioration; there are alternative solutions, each with benefits and liabilities.

Bob Hartzler is an architectural conservator at Fort Union National Monument, and has an MS in Historic Preservation from the University of Pennsylvania.

A limited number of copies of the full report text are available by writing to: Jake Barrow, Conservation Program, National Park Service, Box 728, Santa Fe, NM 87504.

Printed on
recycled paper

FIRST CLASS MAIL
Postage & Fees Paid
U.S. Department of the Interior
G-83

0
U.S. GOVT. PRINTING OFC.
CLASSIFICATION
LIBRARY PROGRAM SERVICE
WASHINGTON DC 20402

END

03-05-98